Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 FEBRUARY 1953

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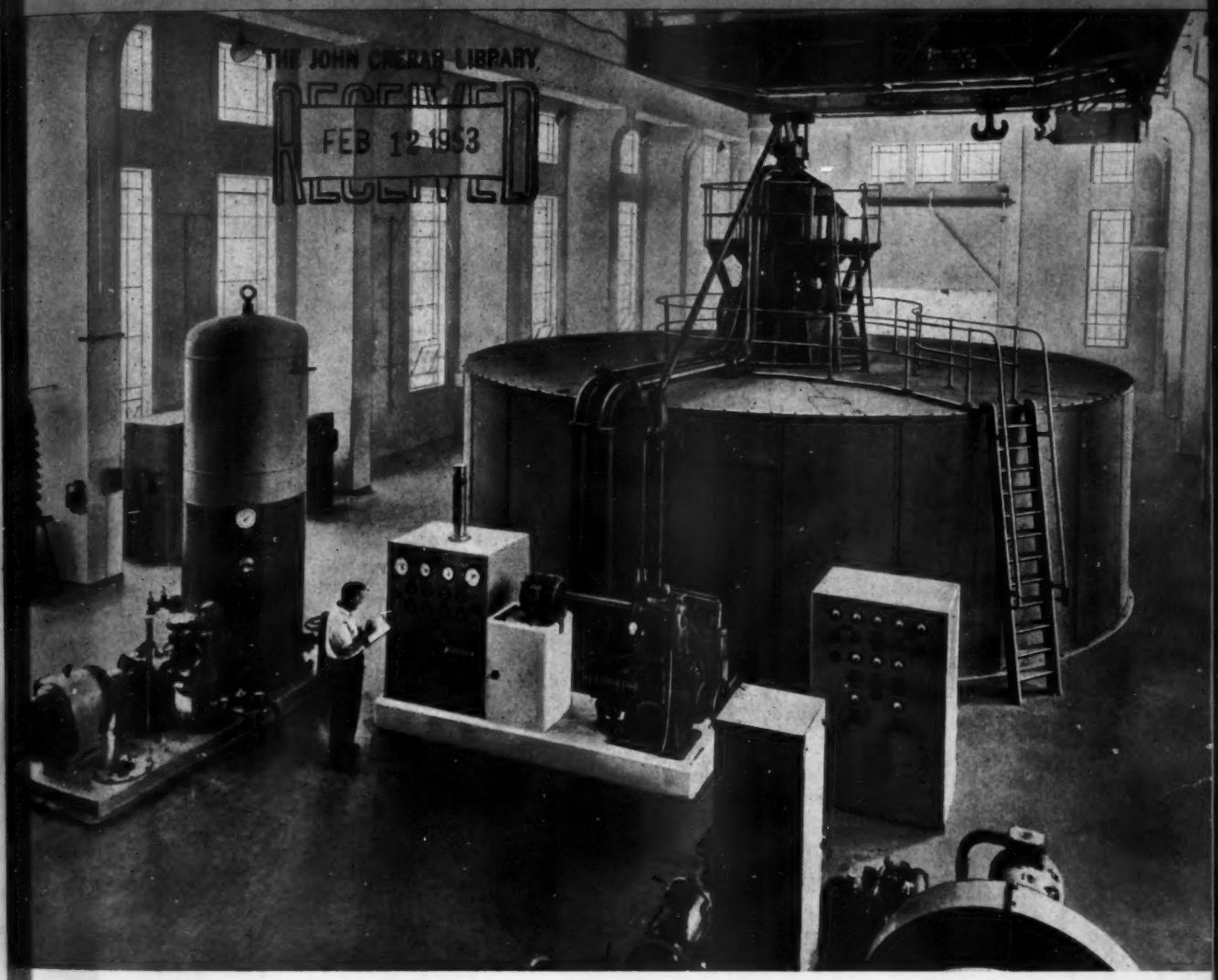
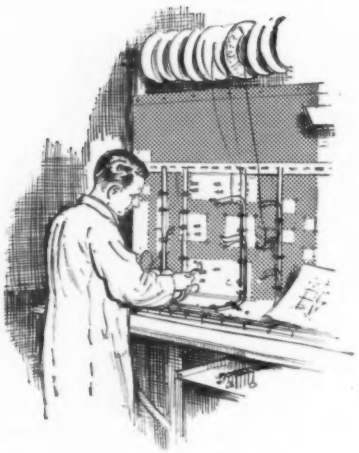


'ENGLISH ELECTRIC'
hydro-electric equipment

The main turbine at Tekapo, New Zealand, operates under a head of 96 ft (max.). Developing 35,000 h.p., it drives a 28,000 kVA "umbrella" type generator. The Company also supplied: 500 h.p. auxiliary generating set; main and service transformers; 11,000 and 400 volt switchgear, control gear and protective equipment.

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2
Hydro-electric Department, Stafford
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON



NOT ALL OF OUR 7,000 PEOPLE are switchgear specialists in the exact sense of the term. But a great many are specialists in some branch of switchgear manufacture, and though they may not fully appreciate all the intricacies of the entire switchgear complex, they know their own part of it backwards. And it is not merely a question of knowing; in all departments there is constant searching for new and better techniques. An illustration of this may be found in the departments concerned with the wiring of control panels. Recently they set to work to devise a new process which has led to a saving of time and material. The wiring and side frames for the control panels are pre-assembled and all connections are cut to length. The complete sub-assembly is then transferred to the shop floor for finishing with detailed components before despatch.

Our primary concern is designing and producing switchgear, so if you have any transmission or control problems, why not talk to us.

If you want to talk switchgear ... talk to Reyrolle

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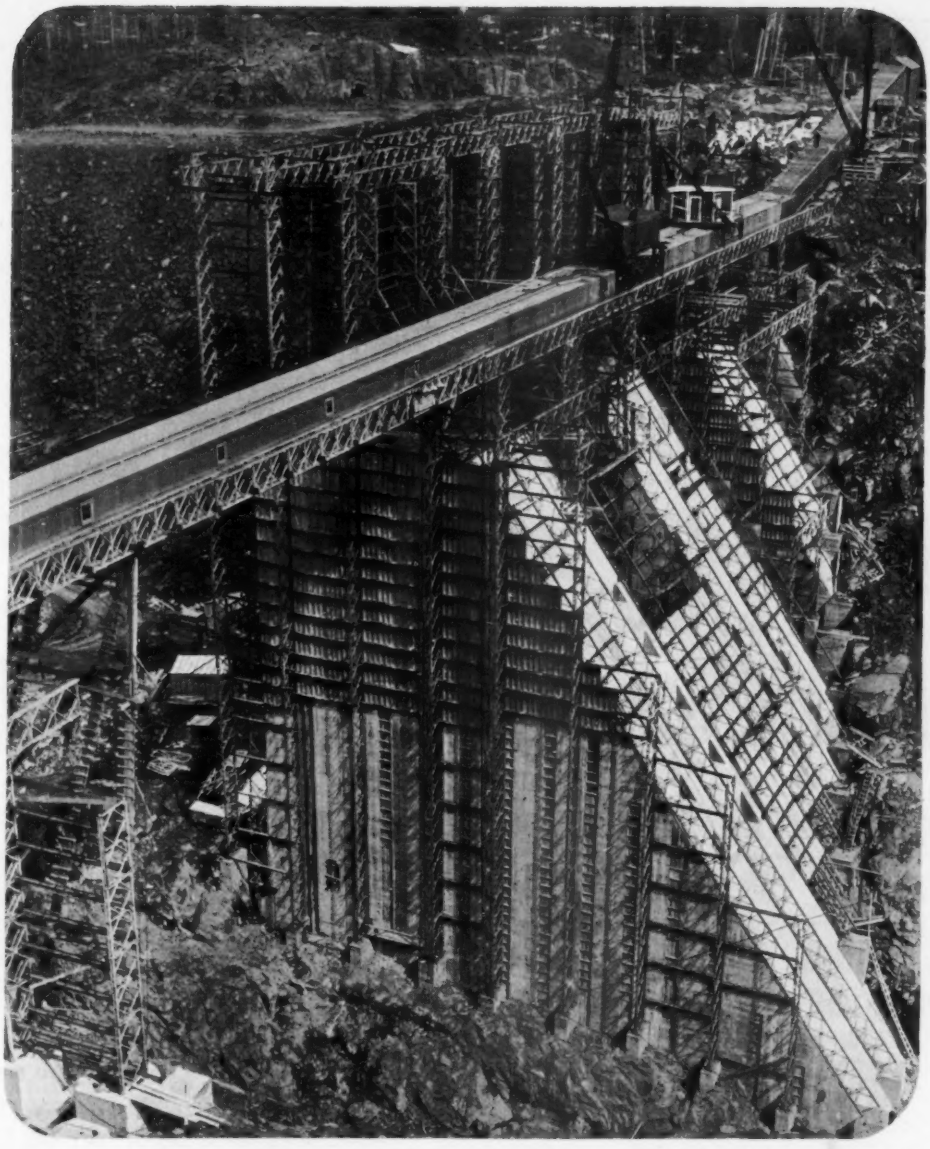

Photograph by courtesy of the Ontario Hydro Electric Commission

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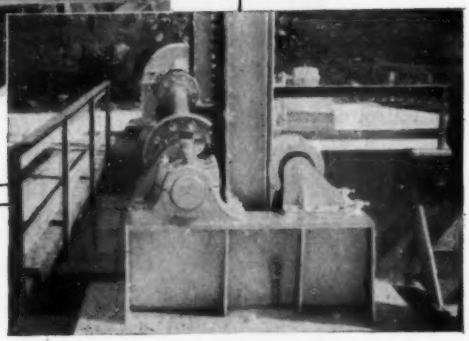
Shop photo of Taintor Gate during fabrication.



Partial view of operating mechanism.

Taintor Gate in position, looking up-stream from log-chute.

Imagineering...

In constructing most Canadian Power Dams, provision must be made for the free movement of logs. The idea of using Taintor Gates to admit water to the log chute was conceived by the Hydro Electric Power Commission of Ontario . . . the Gate and all operating mechanism was designed and fabricated by Canadian Vickers. Thus imagination plus engineering know-how achieved a new and totally satisfactory answer to an old problem.

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HACKBRIDGE Transformers include some of the world's largest units — in capacities up to 94,000 kVA. three-phase—many of these being in service in hydro-electric power stations.

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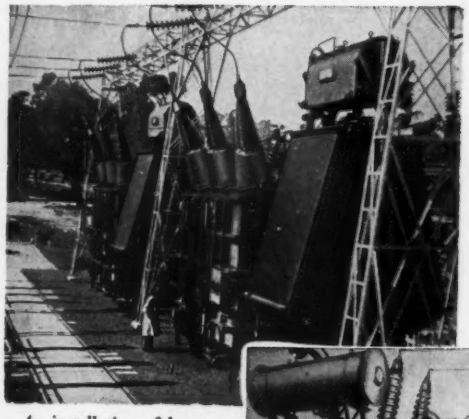
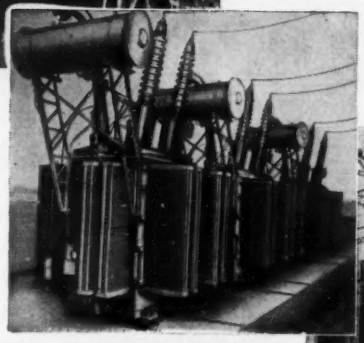
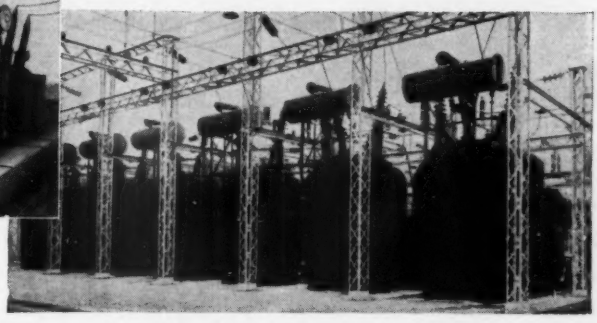


An installation of large Hackbridge transformers in Australia.



Three 6,666 kVA single-phase Hackbridge transformers forming 20,000 kVA 110/38.5/6.6 kV. 3-phase bank.



Two 18,500 kVA. 3-phase 102/11/6.6 kV. banks of Hackbridge transformers installed in Tasmania.

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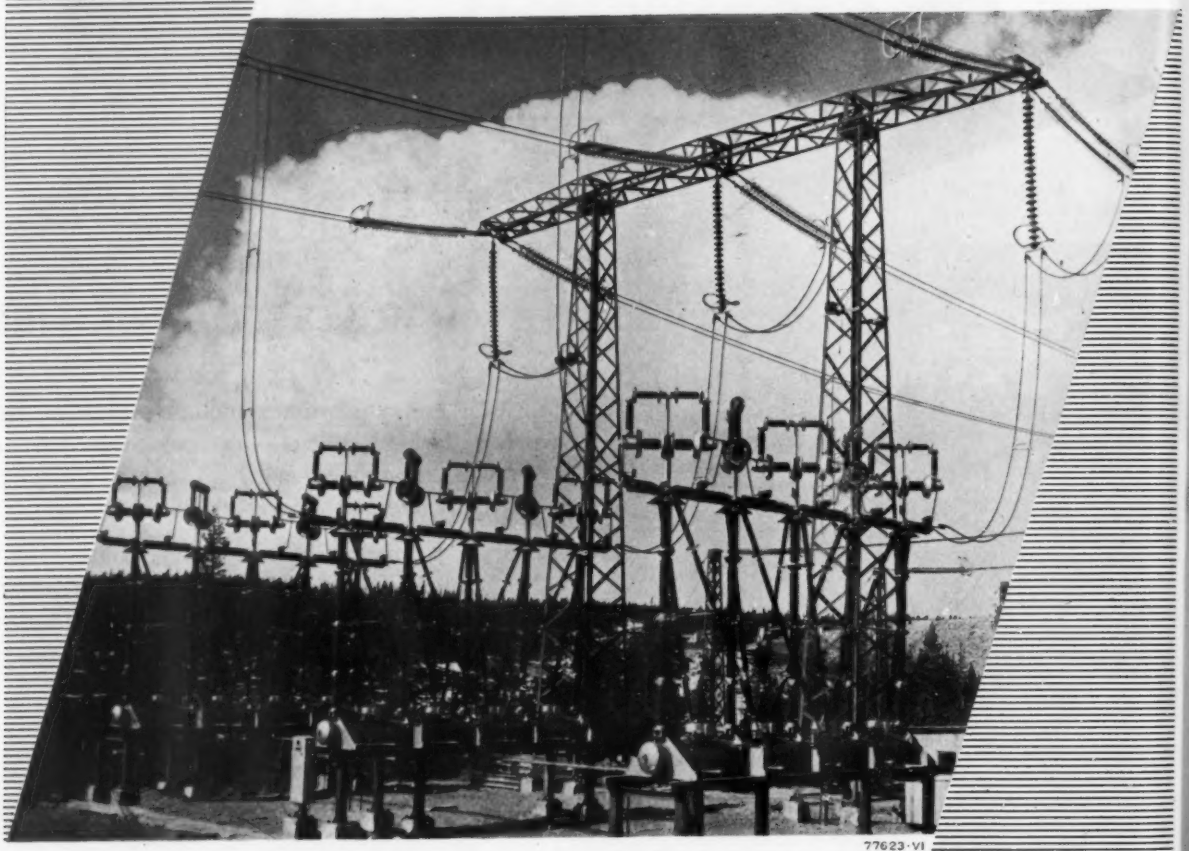
BROWN BOVERI

400 kV



77623-VI

Brown Boveri 400-kV air-blast circuit-breaker in Harspranget power station (Sweden).

Ten of these circuit-breakers have been ordered for the world's first 380-kV system in Sweden. The first was commissioned in May 1952 and field acceptance tests proved that the severest conditions can be coped with.

We build air-blast circuit-breakers assembled from proved standardised units manufactured on batch-production lines, for voltages up to 400-kV, and symmetrical breaking capacities up to 8000 MVA.

Advantages : Short breaking time, high breaking capacity, suitable for single or three-phase reclosing, simple erection, light weight, no inflammable oil.

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Boving

The Waitaki power station is at present being extended with two BOVING-FRANCIS turbines. The station will then contain seven main turbines, all but the third and fourth being supplied by BOVING. The fabricated runner for one of these turbines is illustrated.

RATING

Nett head	70 ft.
Output	23,000 b.h.p.
Speed	125 r.p.m.
Type	Vertical BOVING-FRANCIS
Diameter of runner	12.3 ft.

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B.C.11

a giant spark between horns . . . .

A giant spark leaps between the horns - the eye records a line of blue fire - the ear rings with its detonation and in the micro-seconds of its travel the camera arrests its motion, pictures its pattern and presents a perfect record for laboratory study.

In this photograph, streamers to the cap of the third unit are clearly shown — information that will help the engineers to progressive improvement - constant research that ensures the consistent quality of T.T. Insulators, thoroughness in design setting a self-imposed standard so high that only the finest skill and craftsmanship can maintain it. The skill and craftsmanship of the Taylor Tunnicliff organisation that has made them Masters of Porcelain Insulation.

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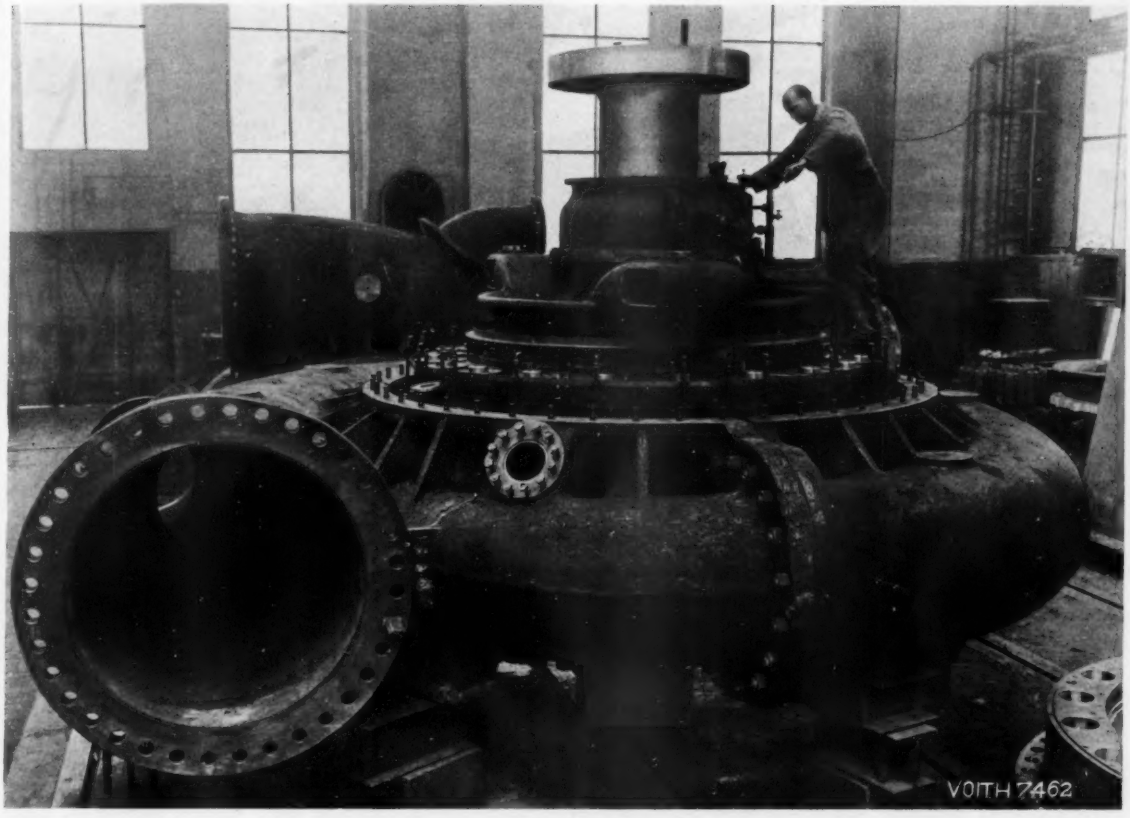

Francis Spiral Turbine, output 48,500 H.P., head 1,114 feet

Kaplan - Francis - and Impulse Turbines

Storage Pumps, Gates of all types, Trash Racks, Trash Rack Rakes, Butterfly Valves, Spherical and Needle Valves, Speed Governors and Gear Drives

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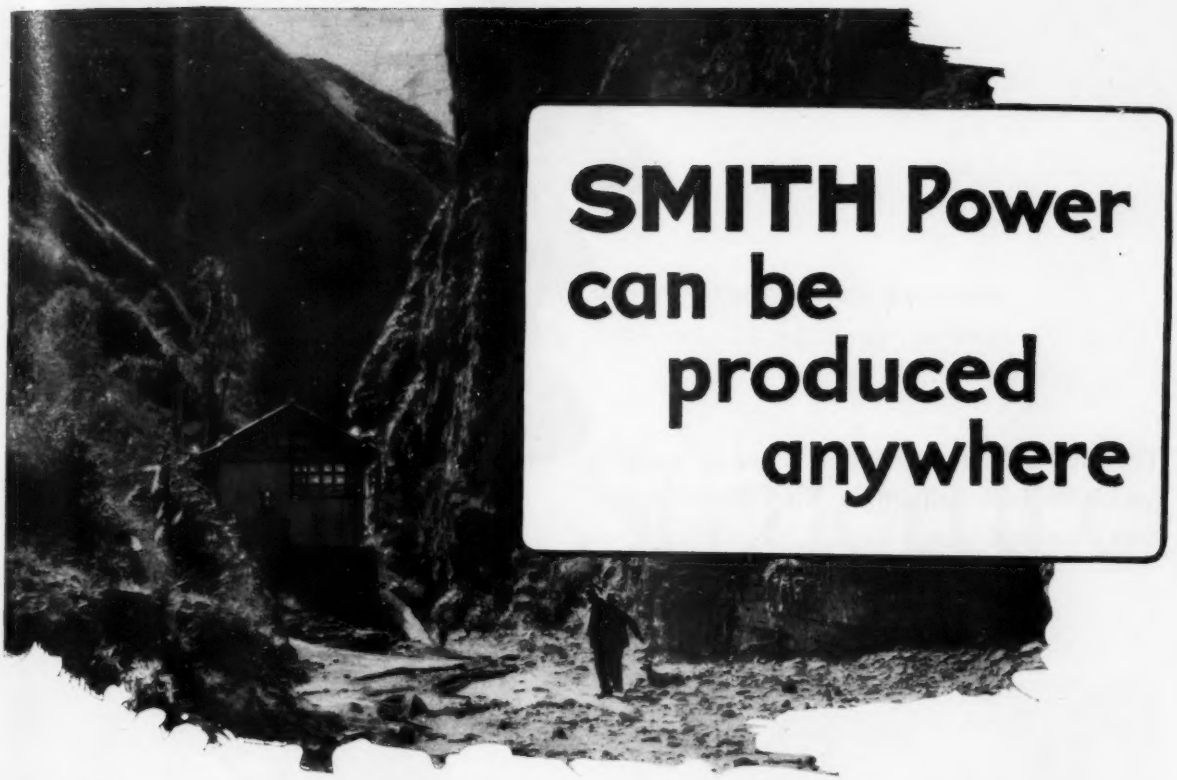

SMITH Power can be produced anywhere

Two pictures tell the story!

Here is a typical example of power produced at a station in a mountainous region, showing how Smith Impulse Turbines provide the people of a remote section with electric current.

The other is a representative Smith-Kaplan installation in a more densely populated flat district, of which there are many throughout the world.

Whatever your problem is; or however difficult it may appear, you will find the answer in a Smith Unit, designed as a result of our 77 years experience in Hydraulics!

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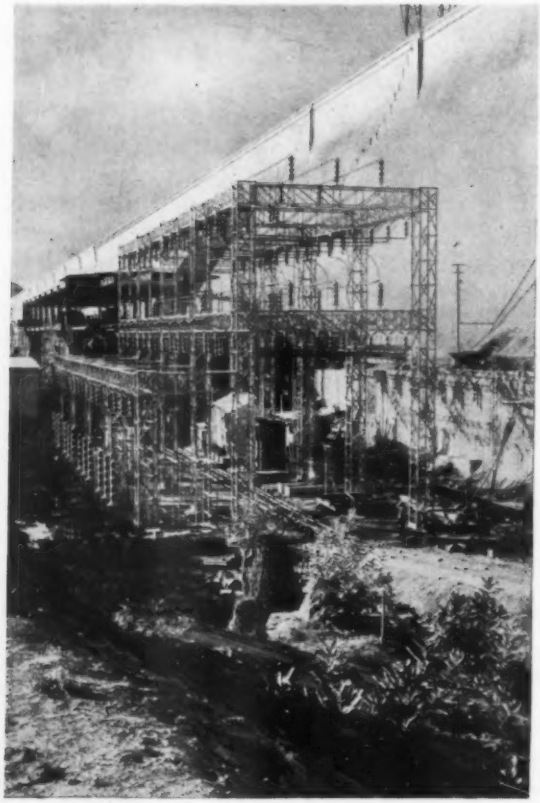
If It's Hydraulics-Put It Up to Us·

POWER by SMITH

The Mettur Dam sub-station is one of many in South India equipped with posts type P.642 for 66KV and 110KV.



Photograph reproduced by courtesy of the main contractors, Messrs. A E.I. (India) Ltd.

S.P.P. POST INSULATORS were specified for the METTUR DAM SUB-STATION MADRAS

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S.P.56

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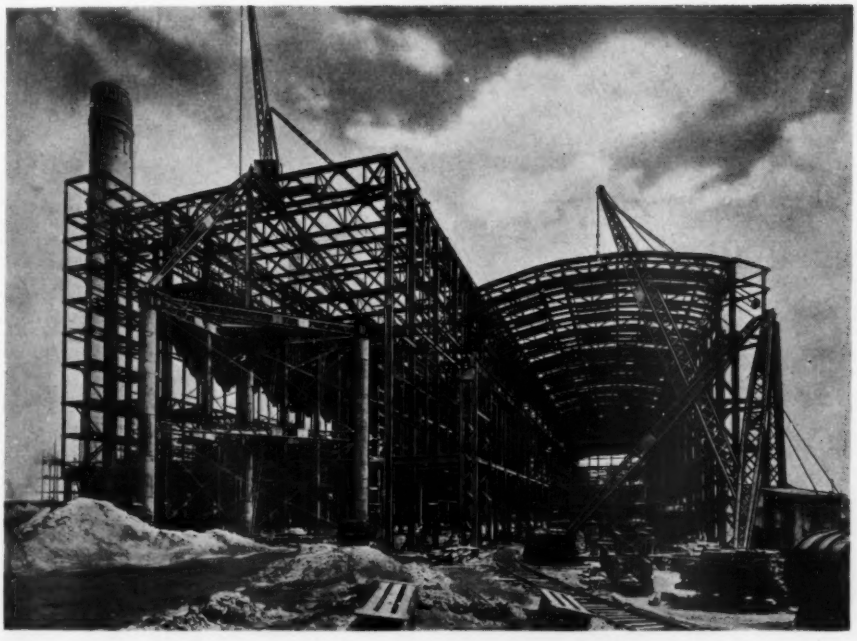

Croydon "B" is one of some dozen post-war major generating stations framed by Arrol structural steelwork.

Consulting Engineers: F. N. Rendell-Baker, M.I.E.E.; C. S. Allott & Son

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The facilities and experience indicated by such a record are at your service anywhere in the world.

Write for General Bulletin No. 201 on Dominion Hydraulic Turbines.

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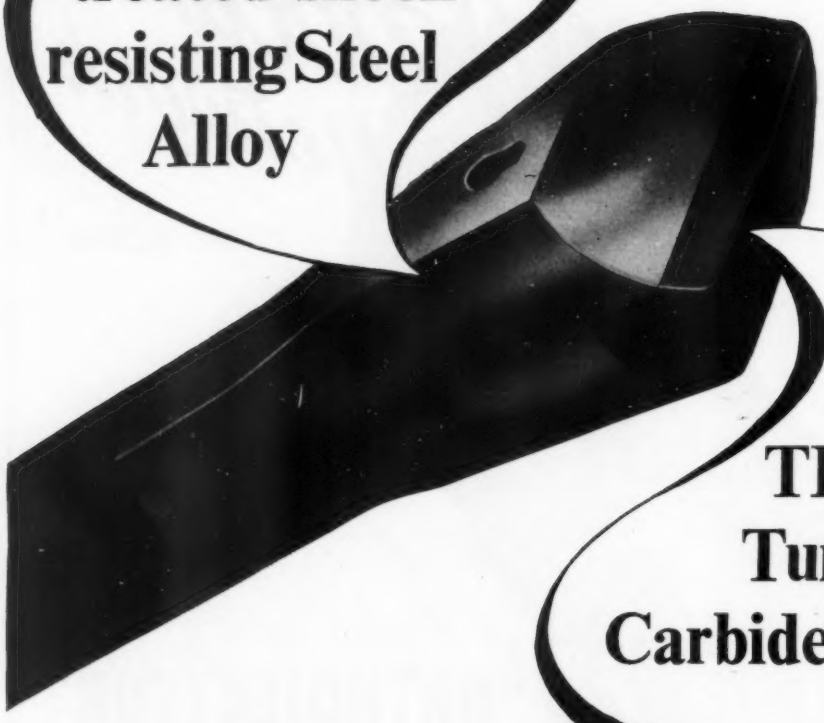

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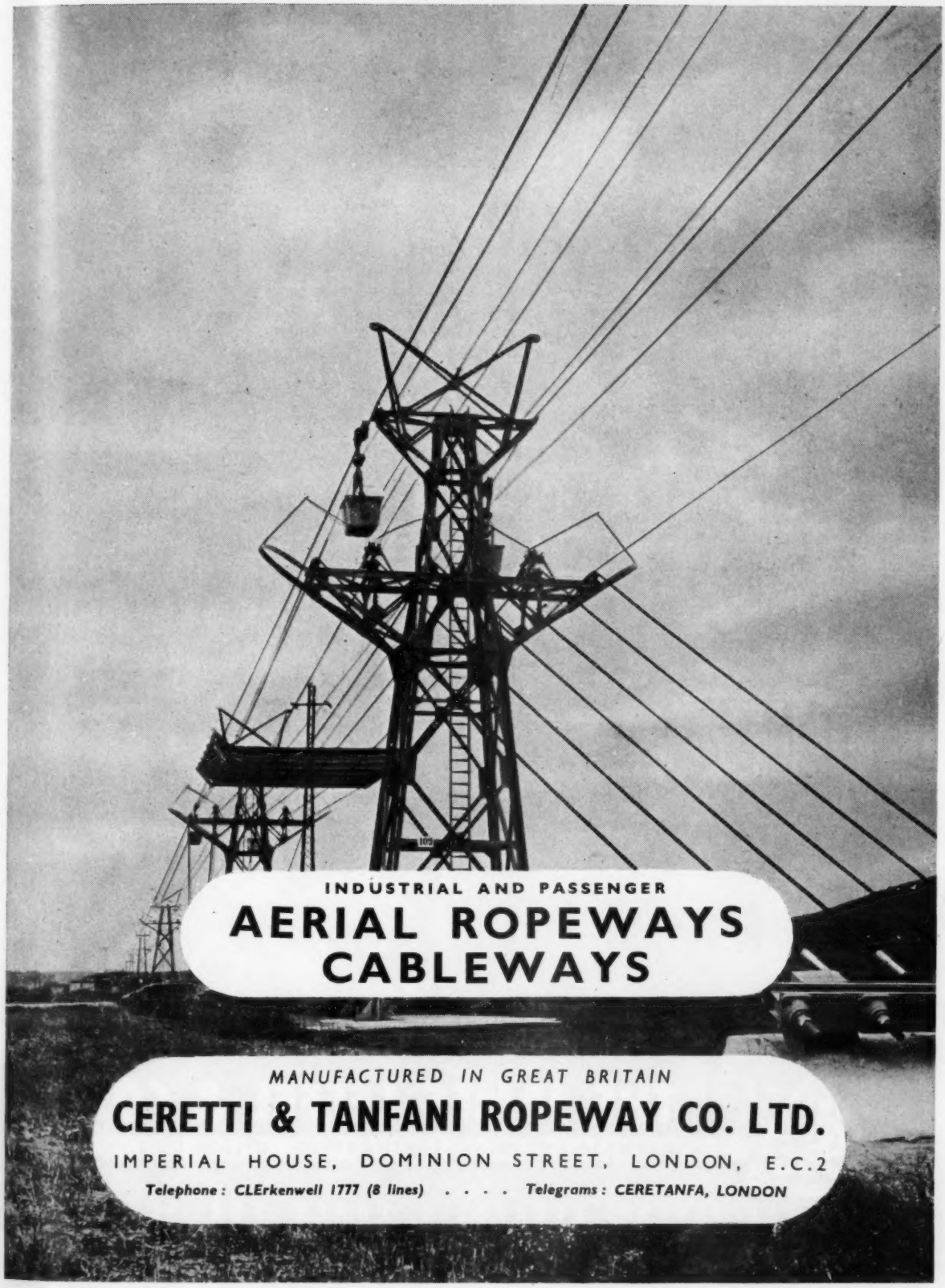
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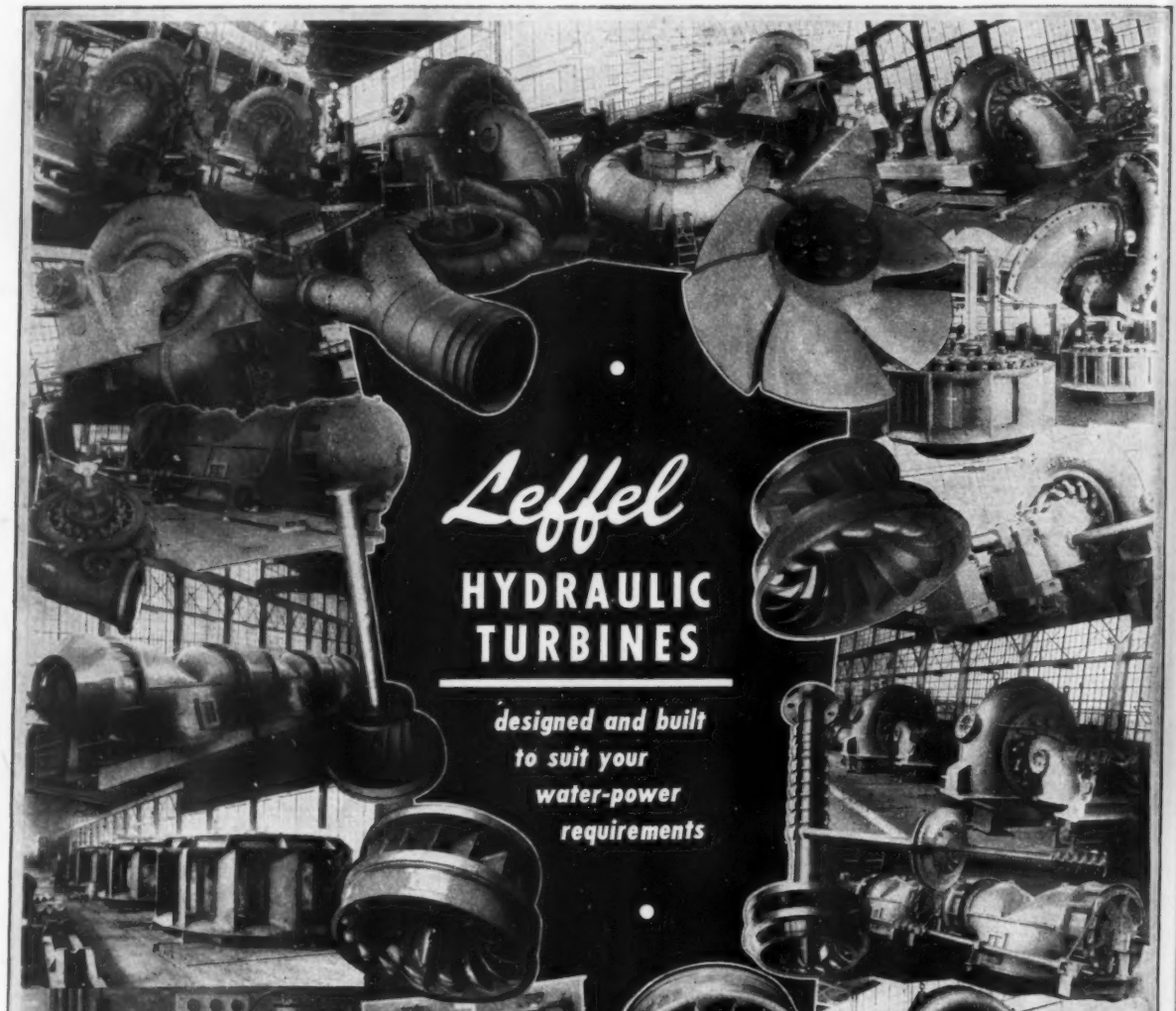

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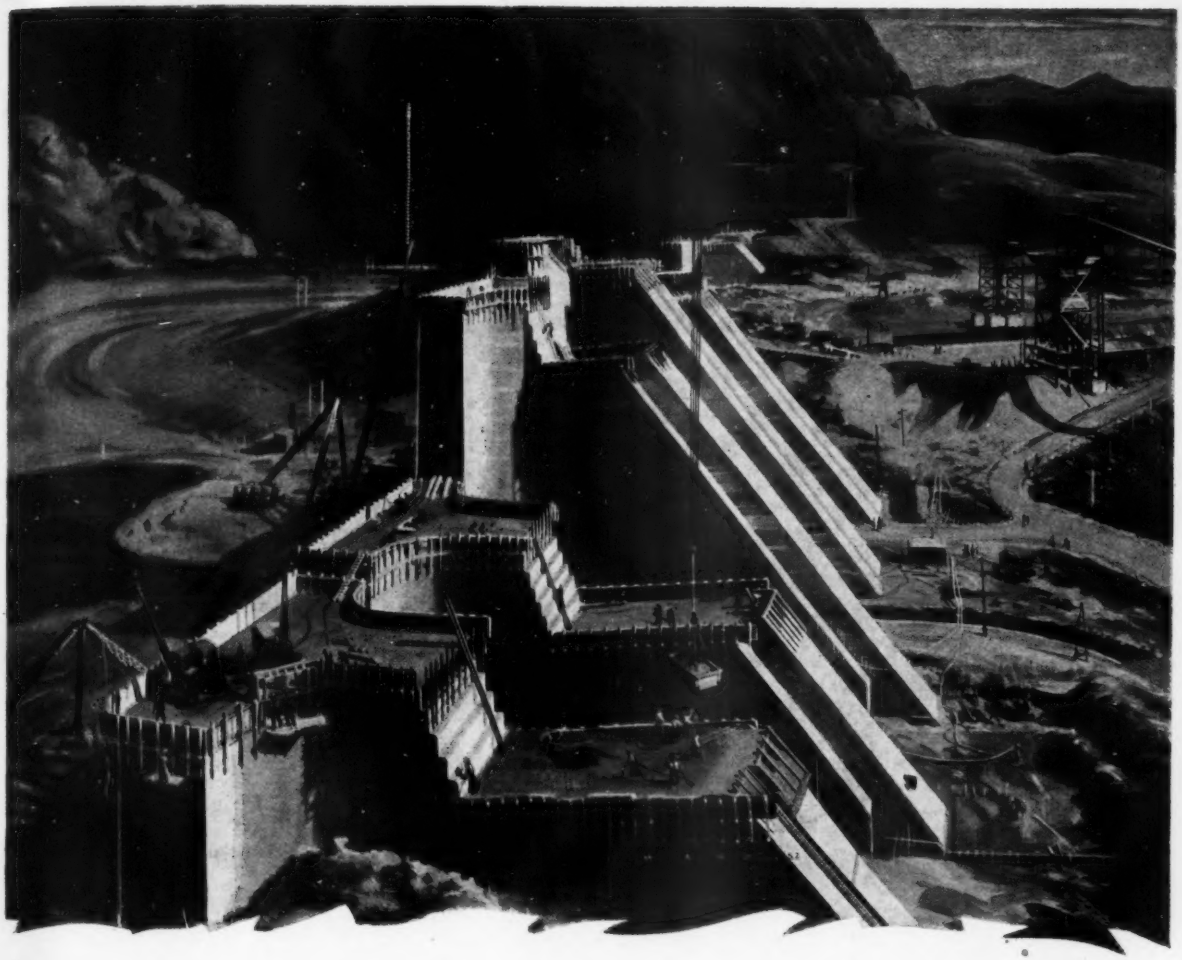

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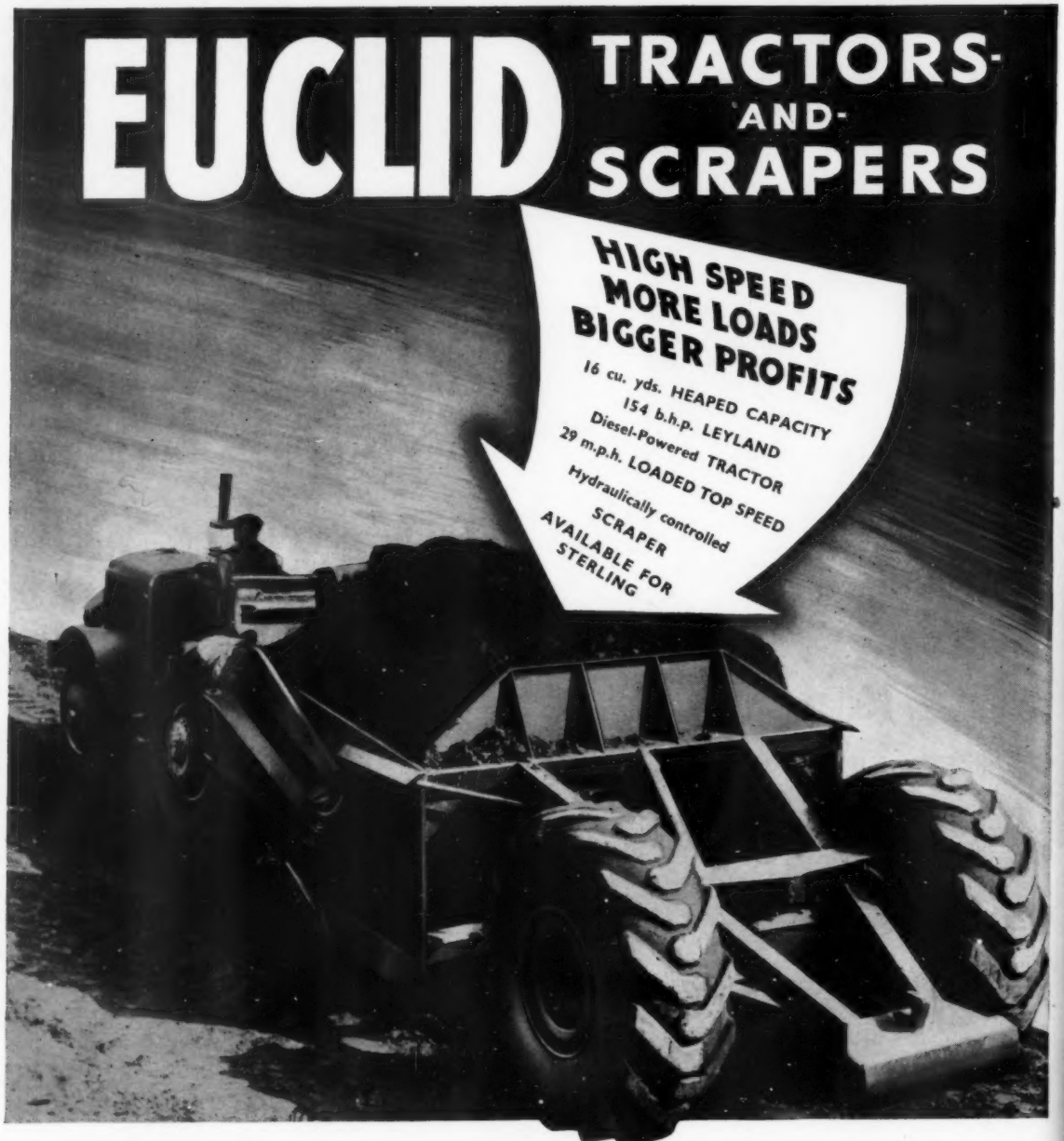

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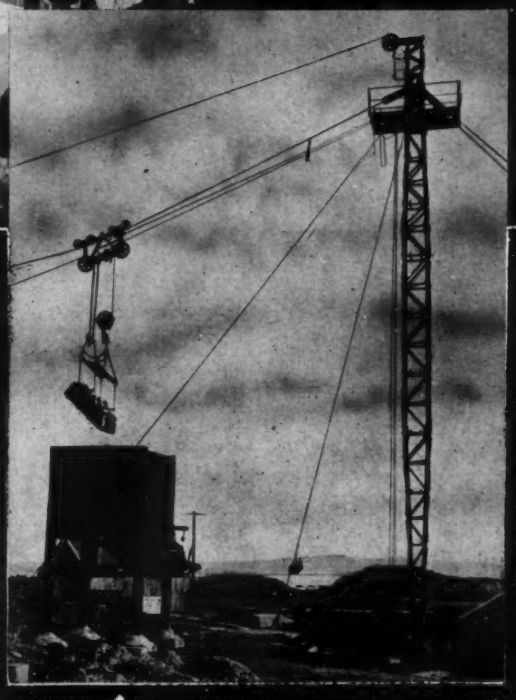

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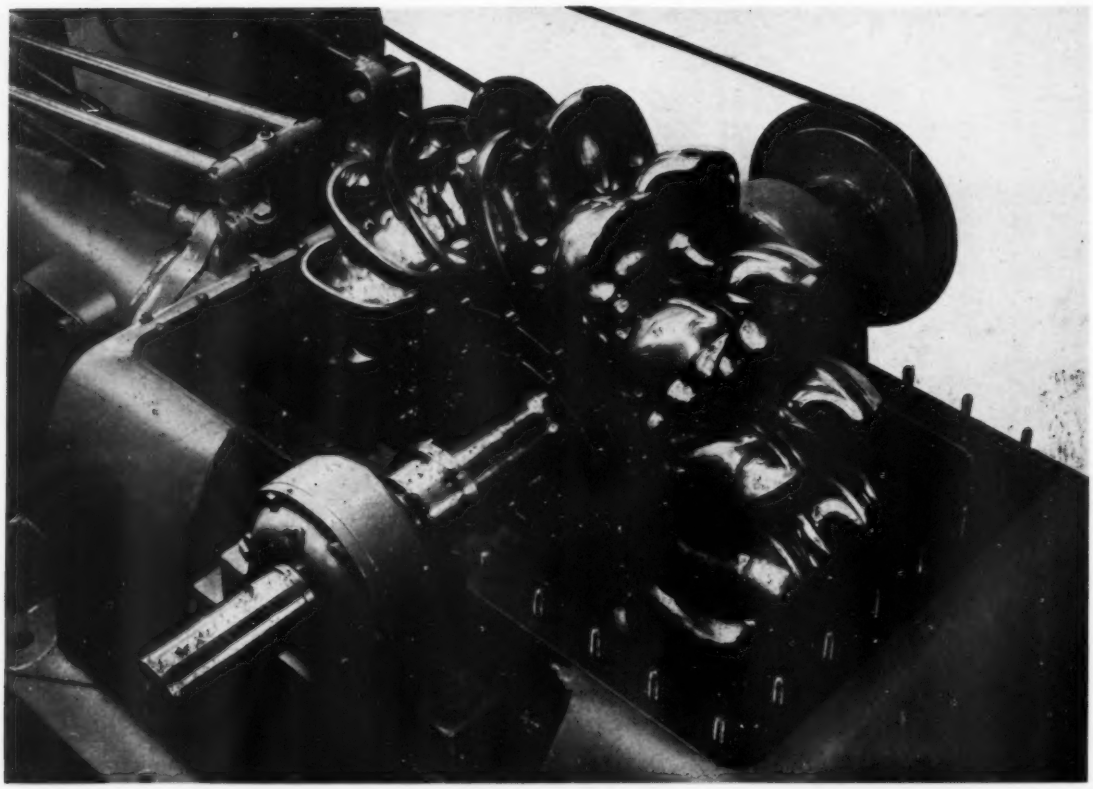

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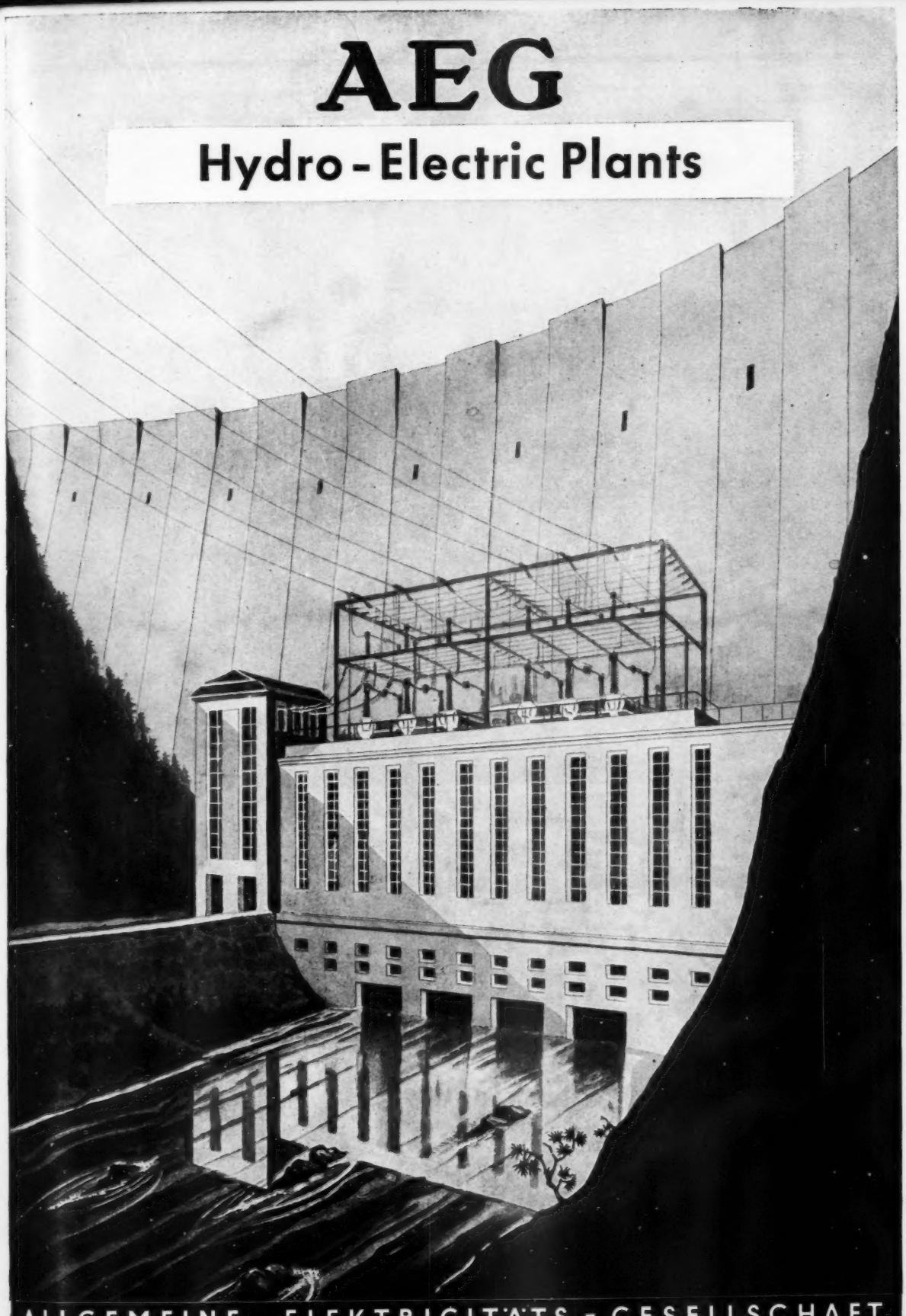

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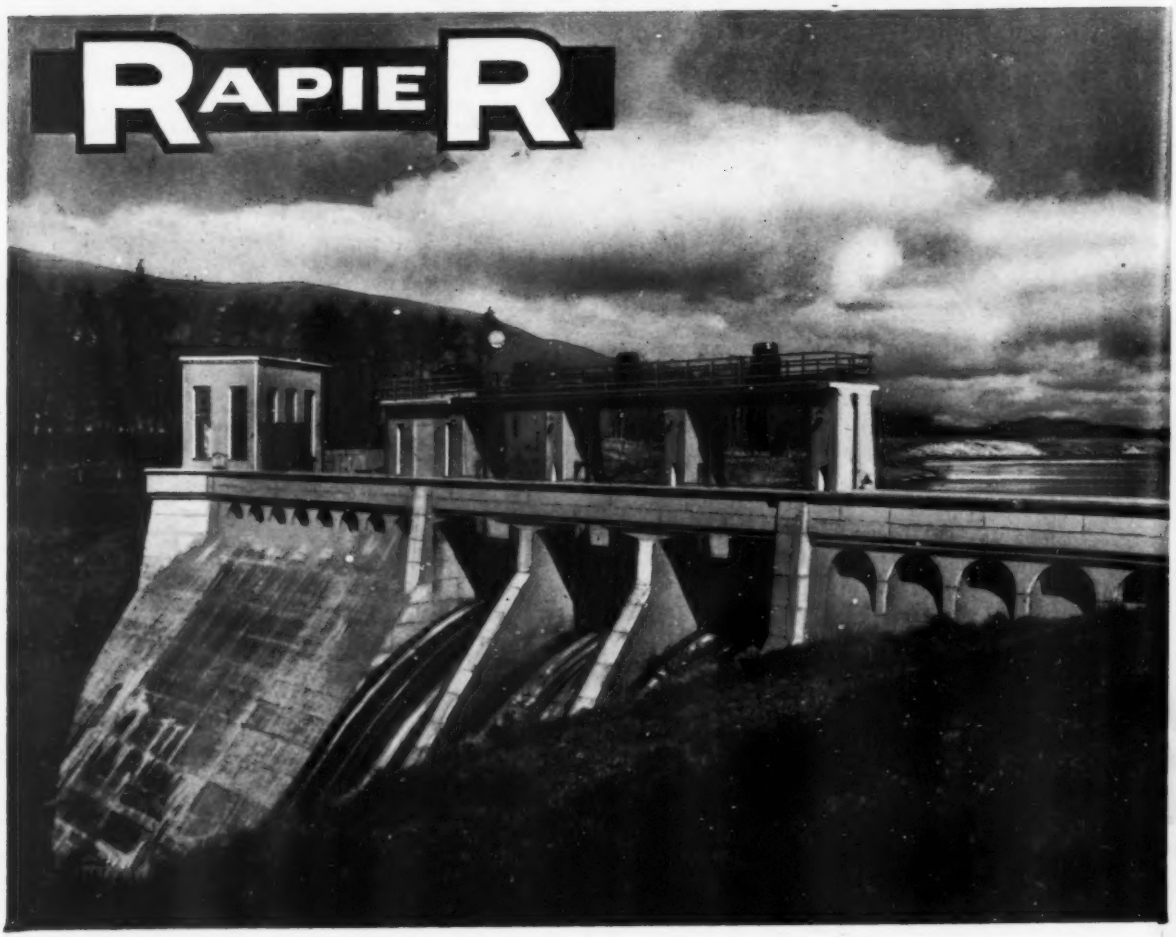

RAPIER

A typical installation of RapieR Gates for Spillway and Tailrace at the dam for Pollaphuca Power Station on the River Liffey, Eire.

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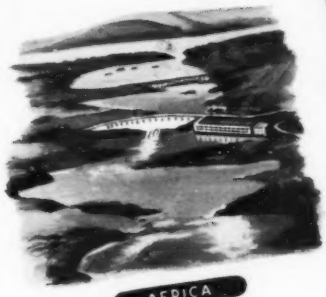
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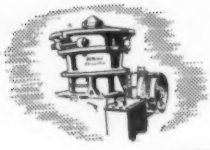

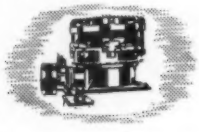

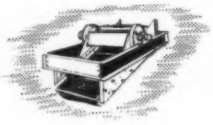

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The three generating units will operate in an underground powerhouse carved out of rock and will be driven by water diverted from the Saõ Francisco River by a 2½-mile diversion dam. Westinghouse is also supplying all transformers and switchgear for the 180,000-kw project.

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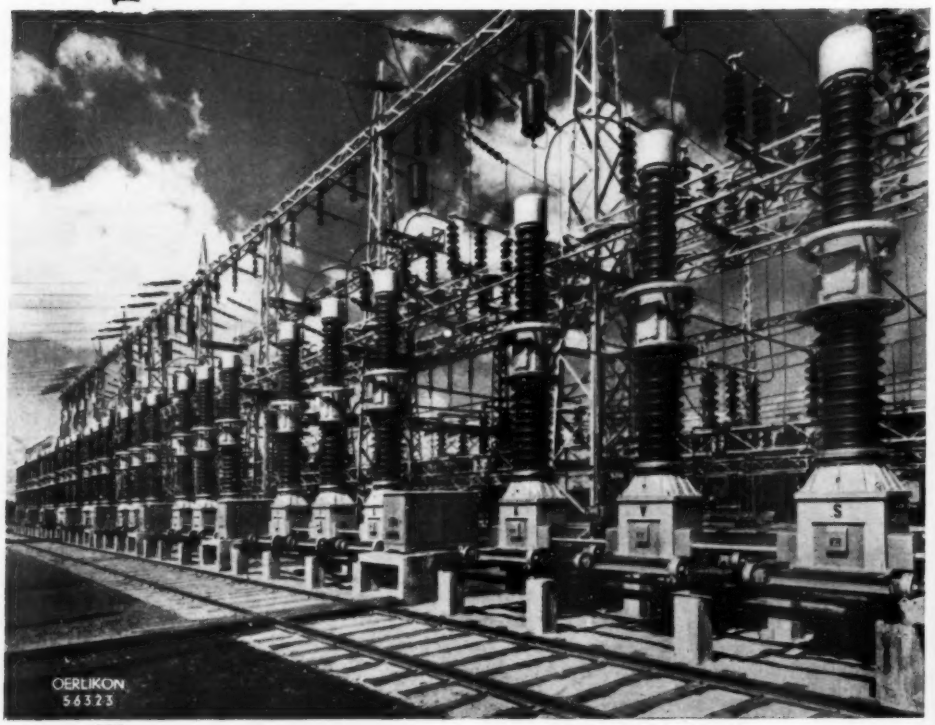

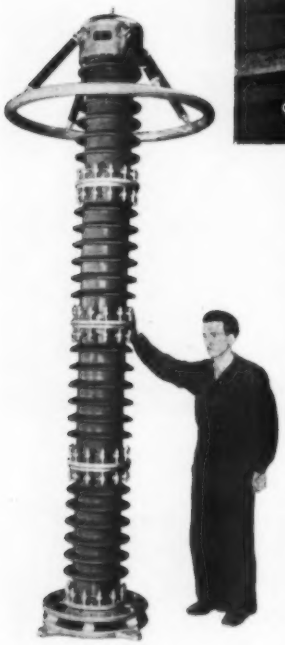

Set of 9 Oerlikon Minimum Oil Content Circuit Breakers, Type TOF, 135 kV, 2500 MVA, in a Transformer Station in Finland.

Picture at left shows an Oerlikon Lightning Arrester for 180 kV. Discharge current 10000 A.

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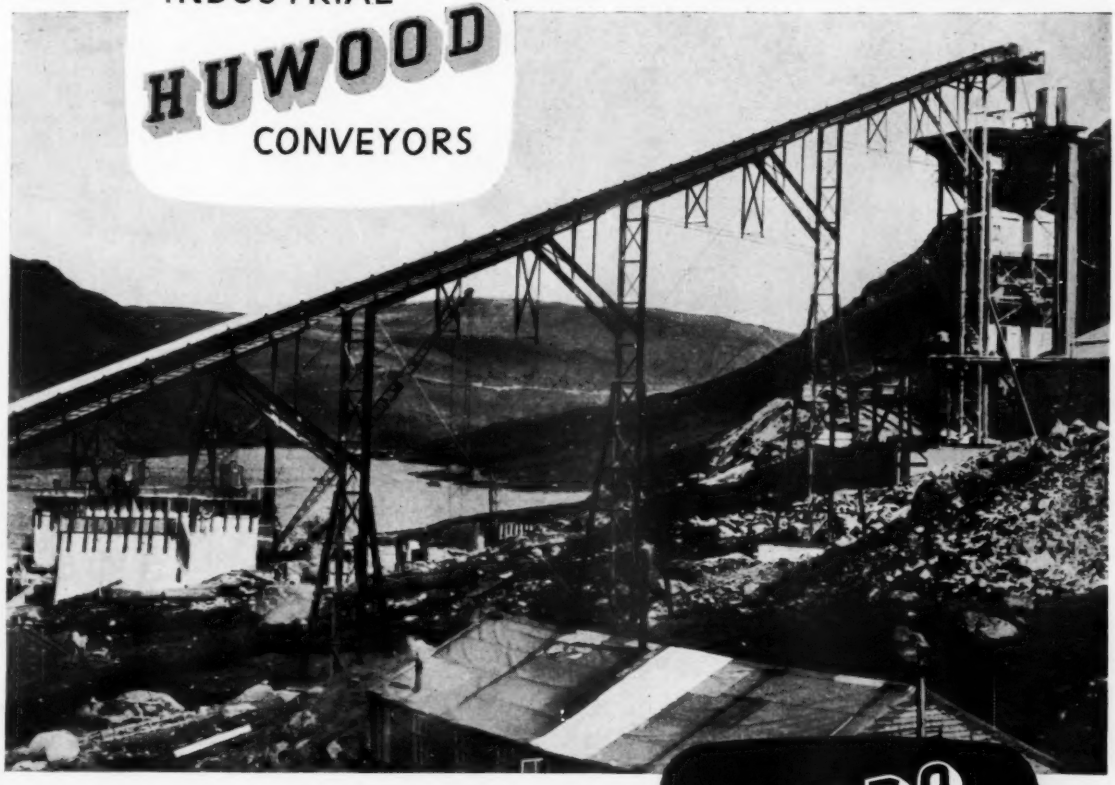

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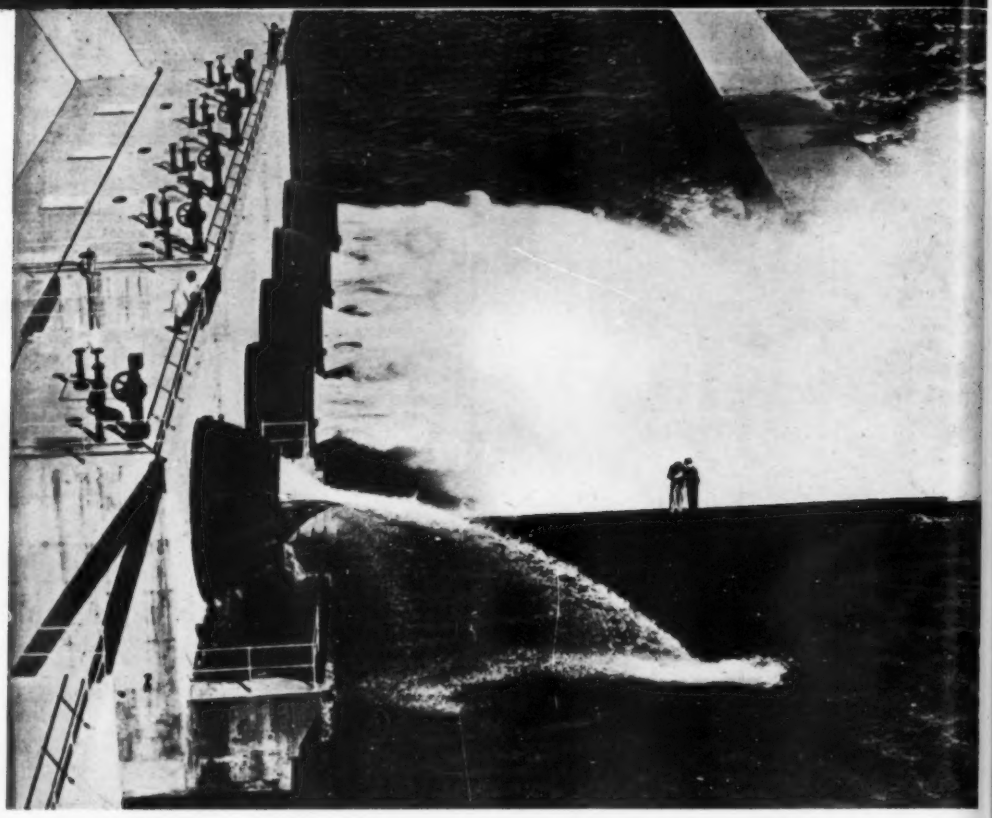

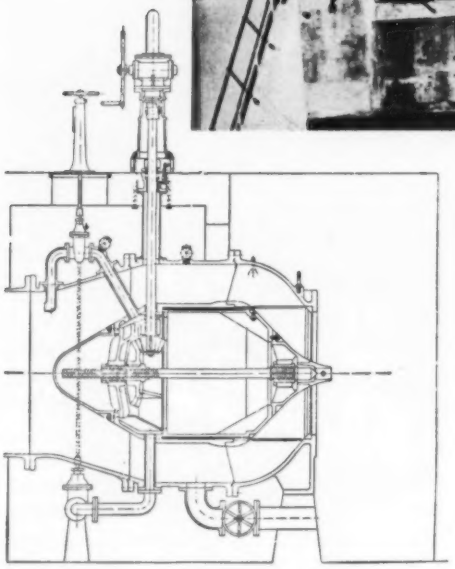

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Full particulars from : J. Blakeborough & Sons Ltd., Brighouse, England.

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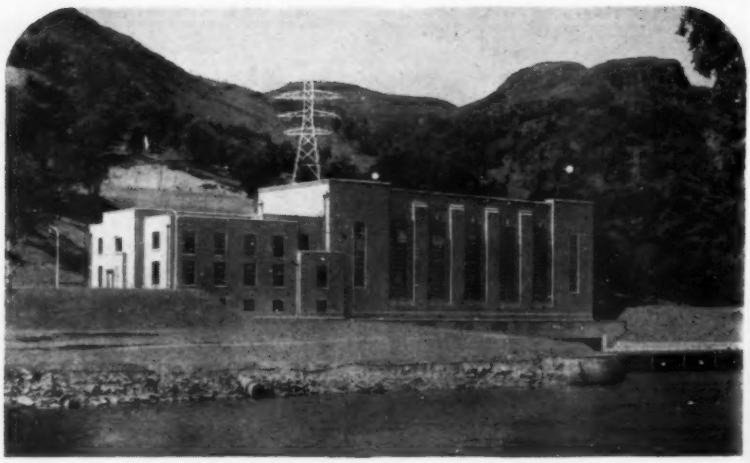

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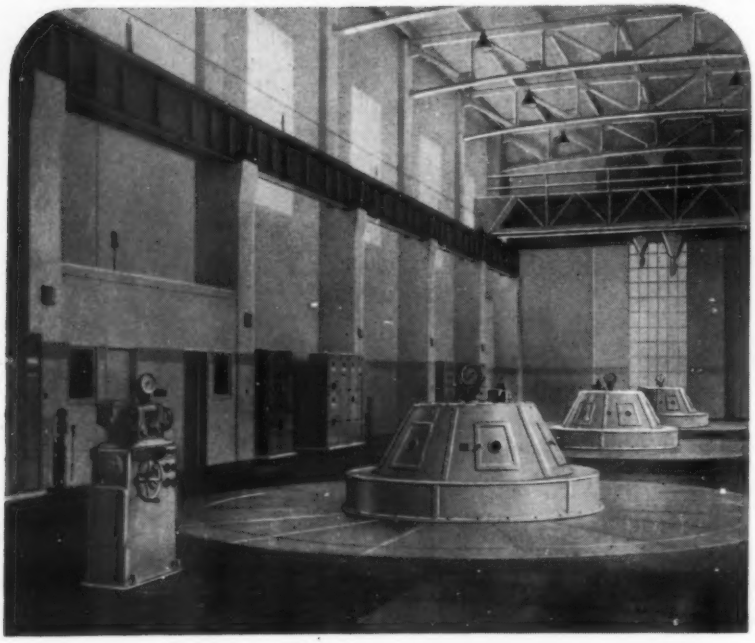

Top : Clunie Power Station — North of Scotland Hydro-electric Board

Left : Main Floor of Clunie machine room showing exciter casings, governor actuators, and control panels for the three BTH 22,667-kVA., 11,000-volt, 3-phase, 50-cycle, 214-r.p.m., vertical water-wheel driven alternators. The size of the alternators can be judged from the diameter of the circular plating.

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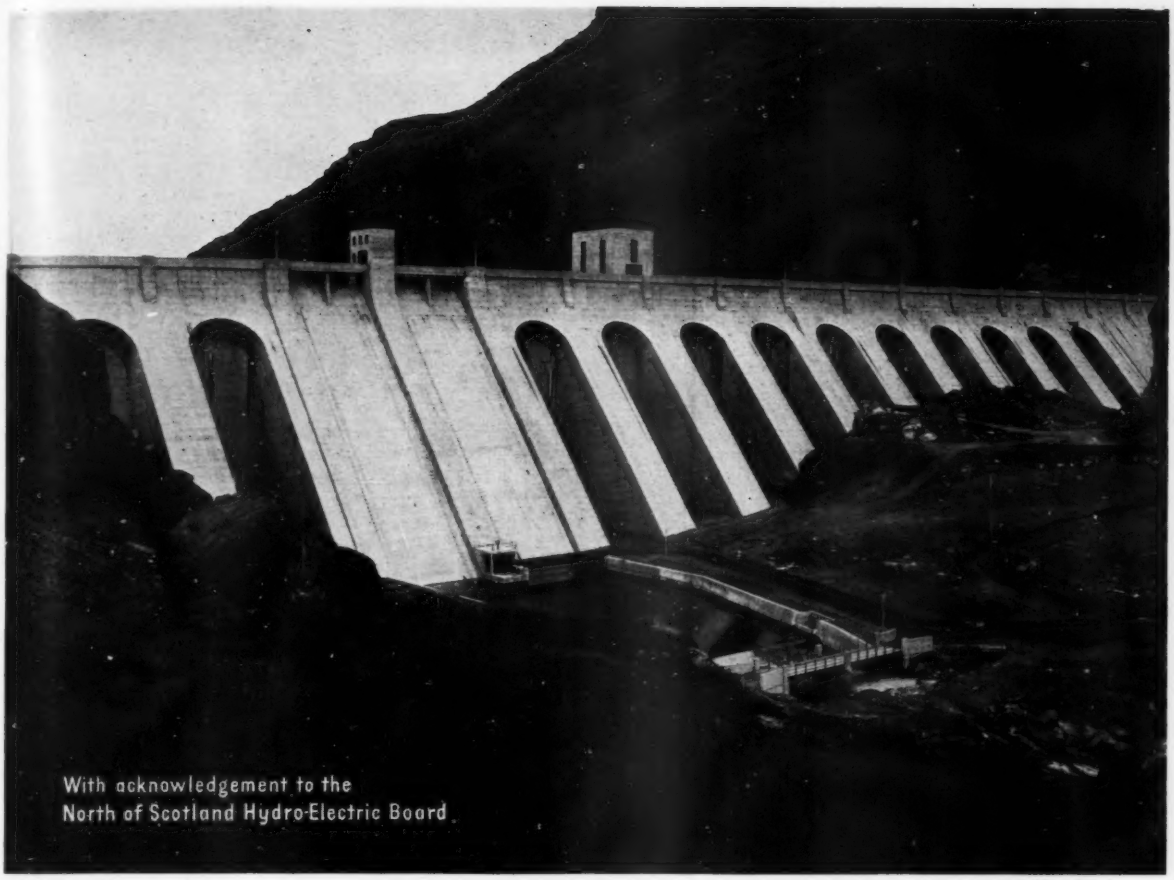

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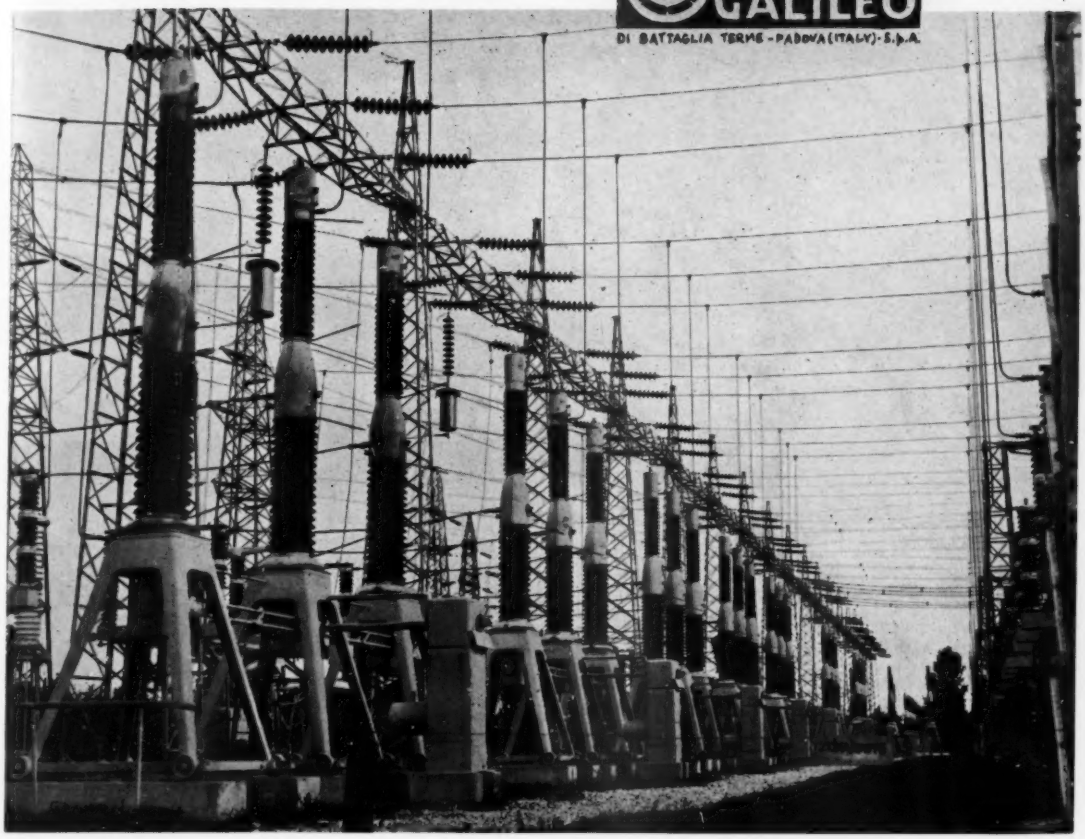

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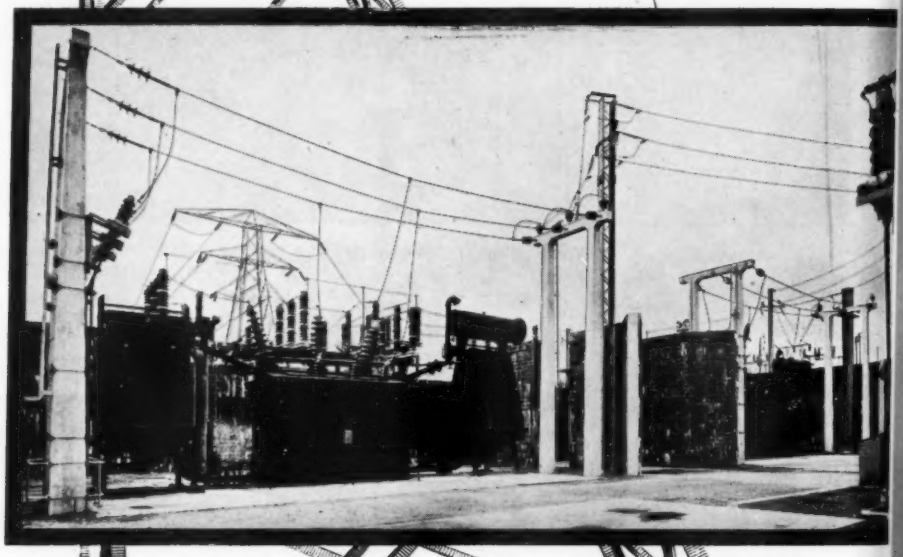

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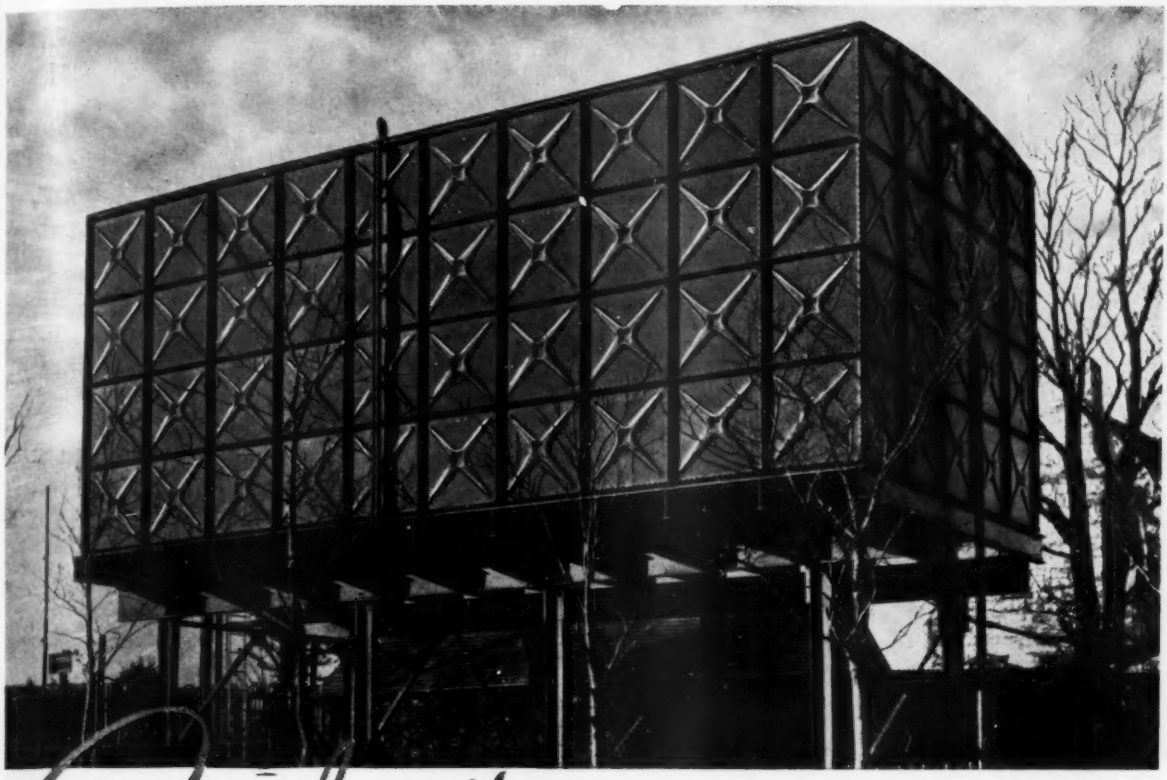

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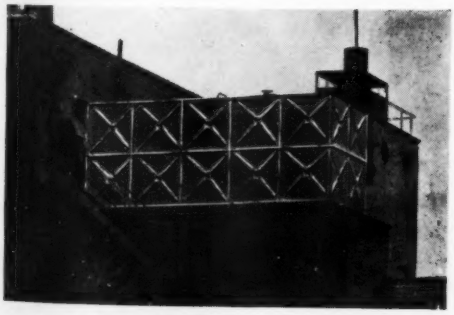

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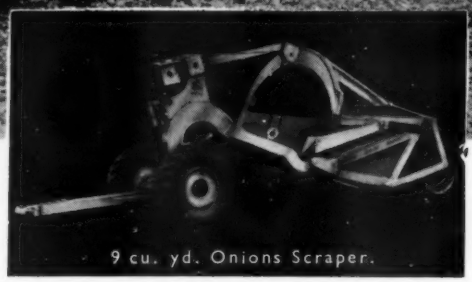

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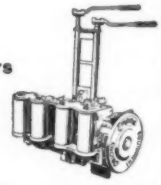

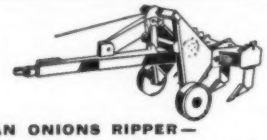

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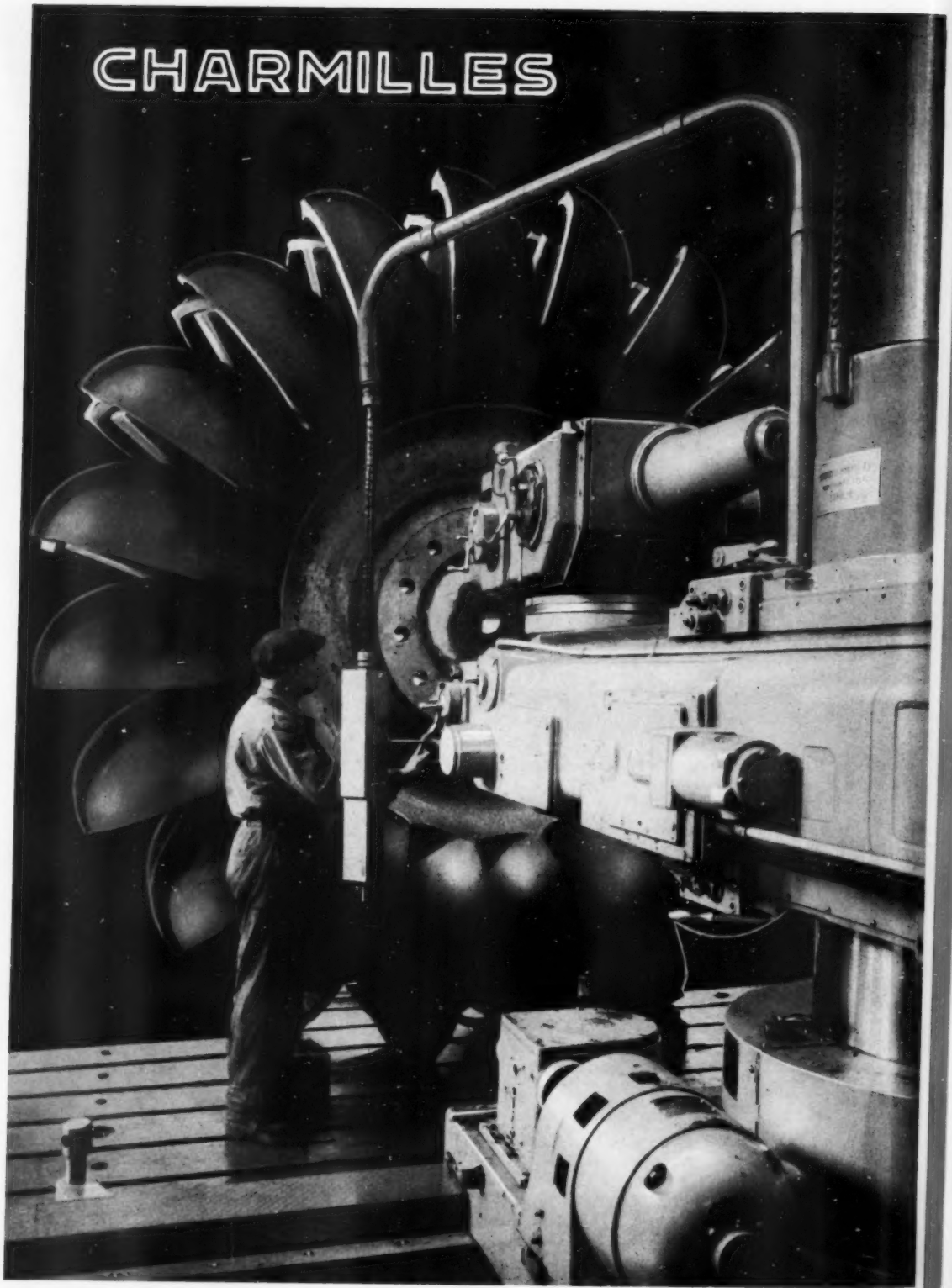

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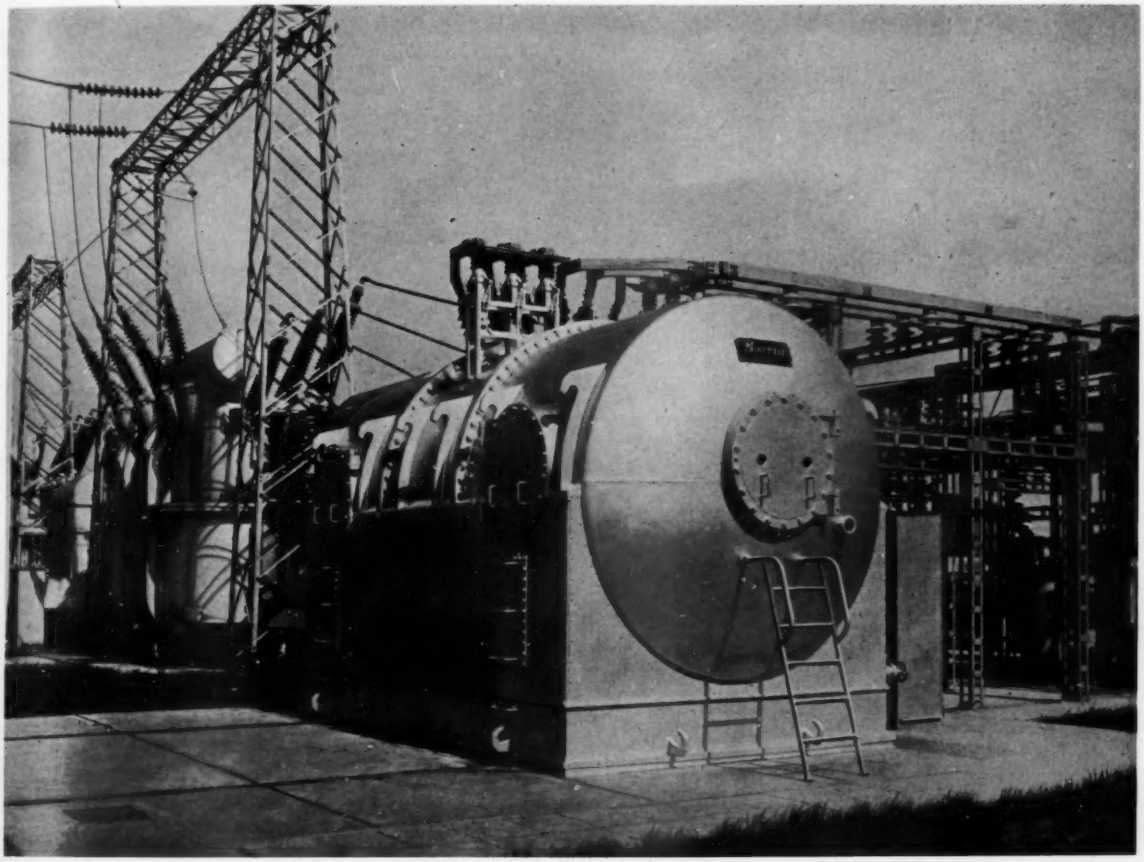

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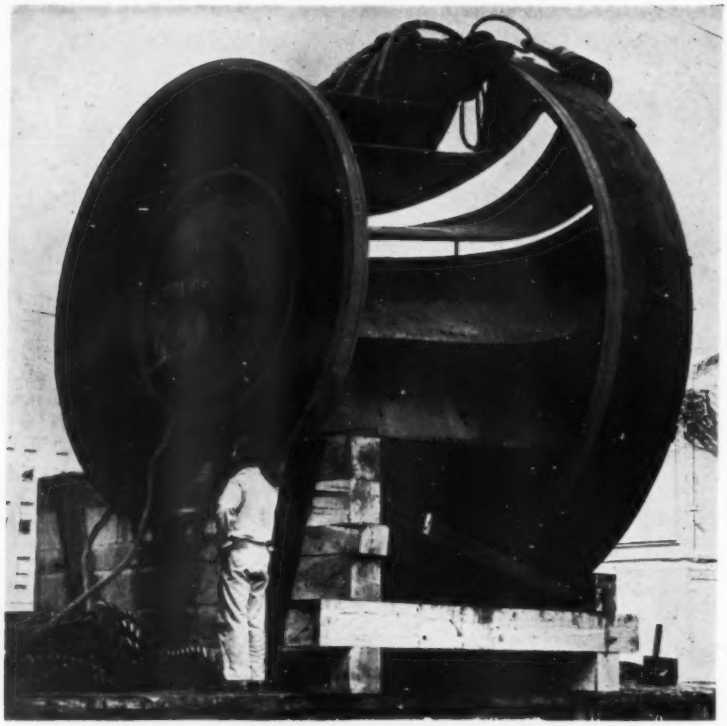

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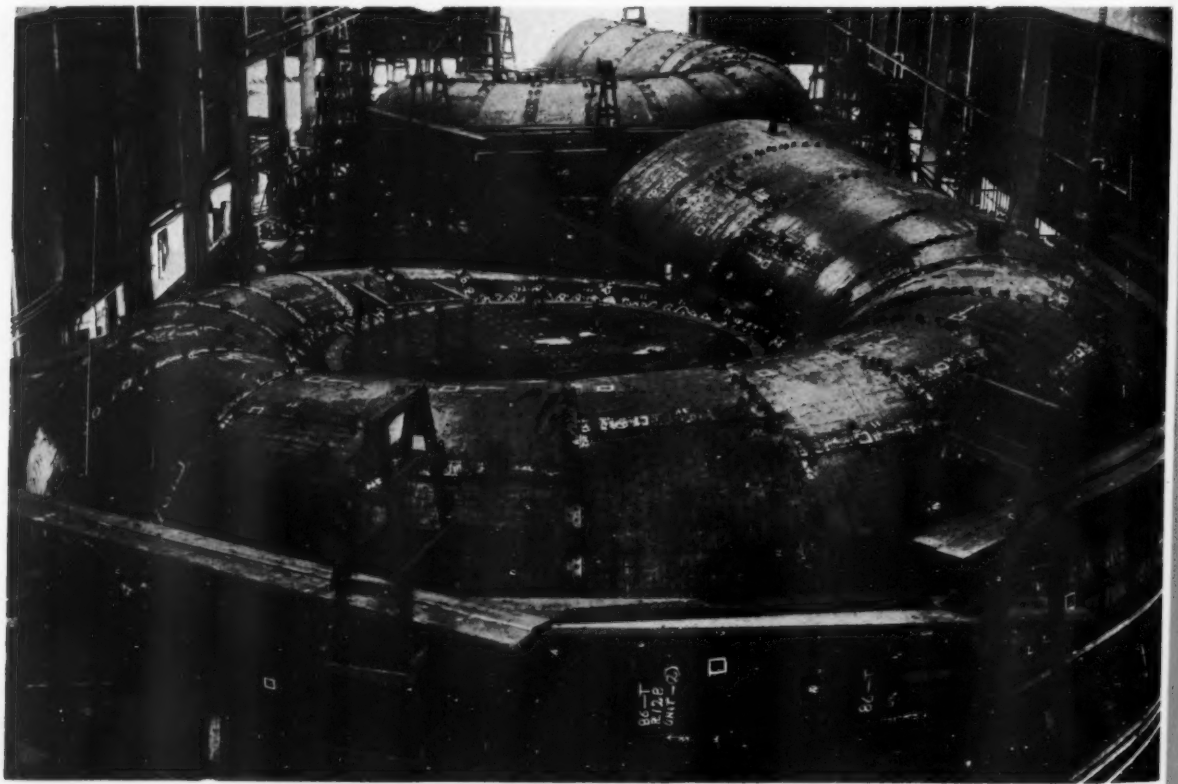

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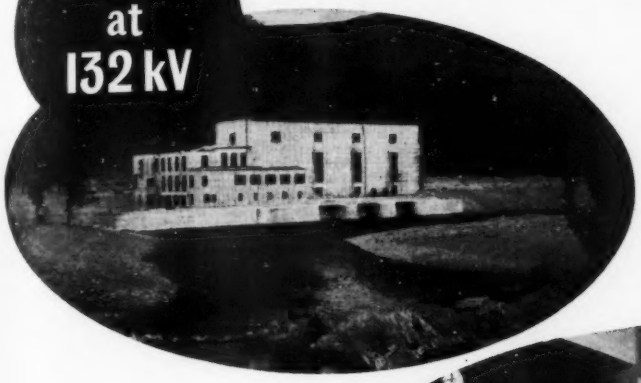

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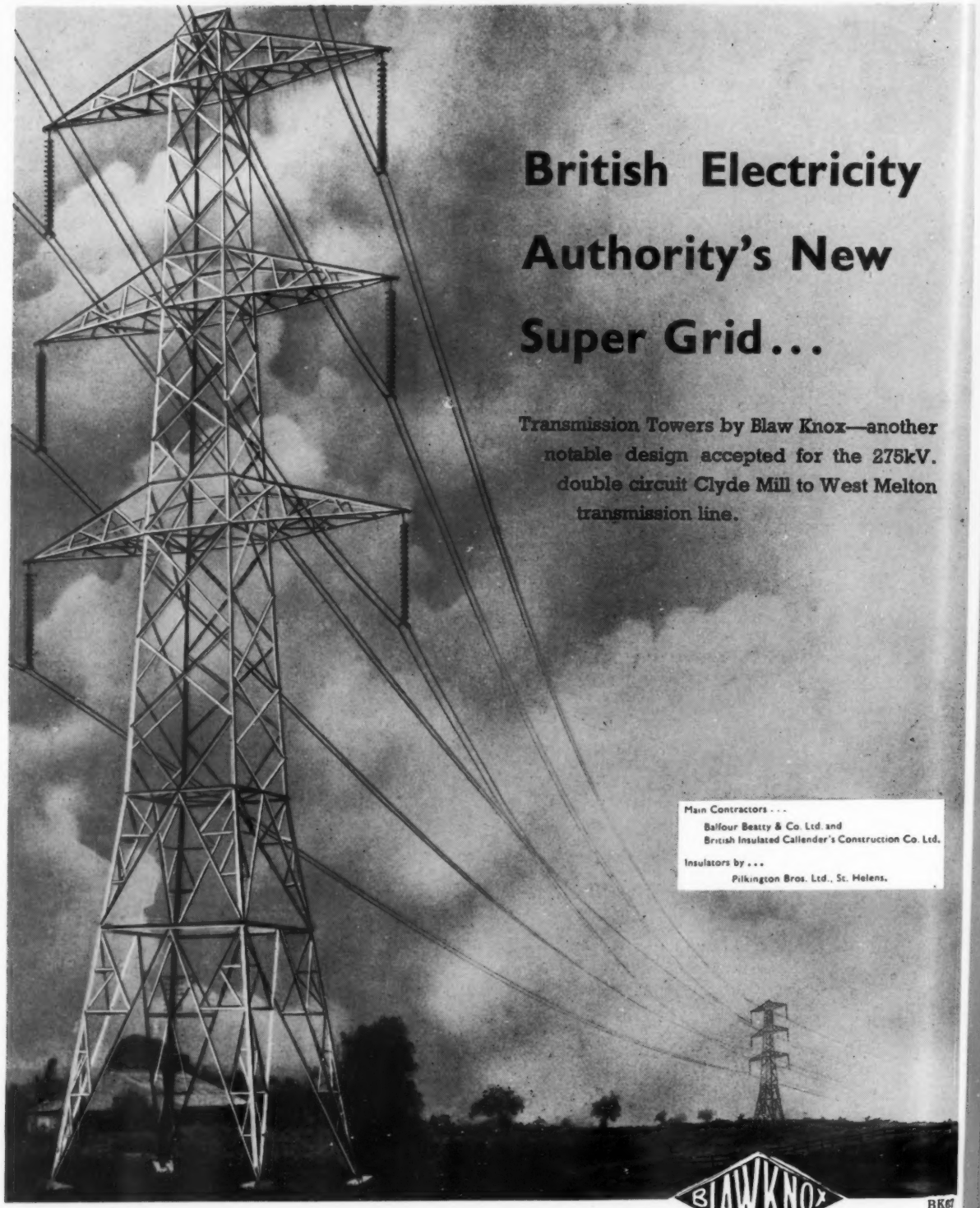
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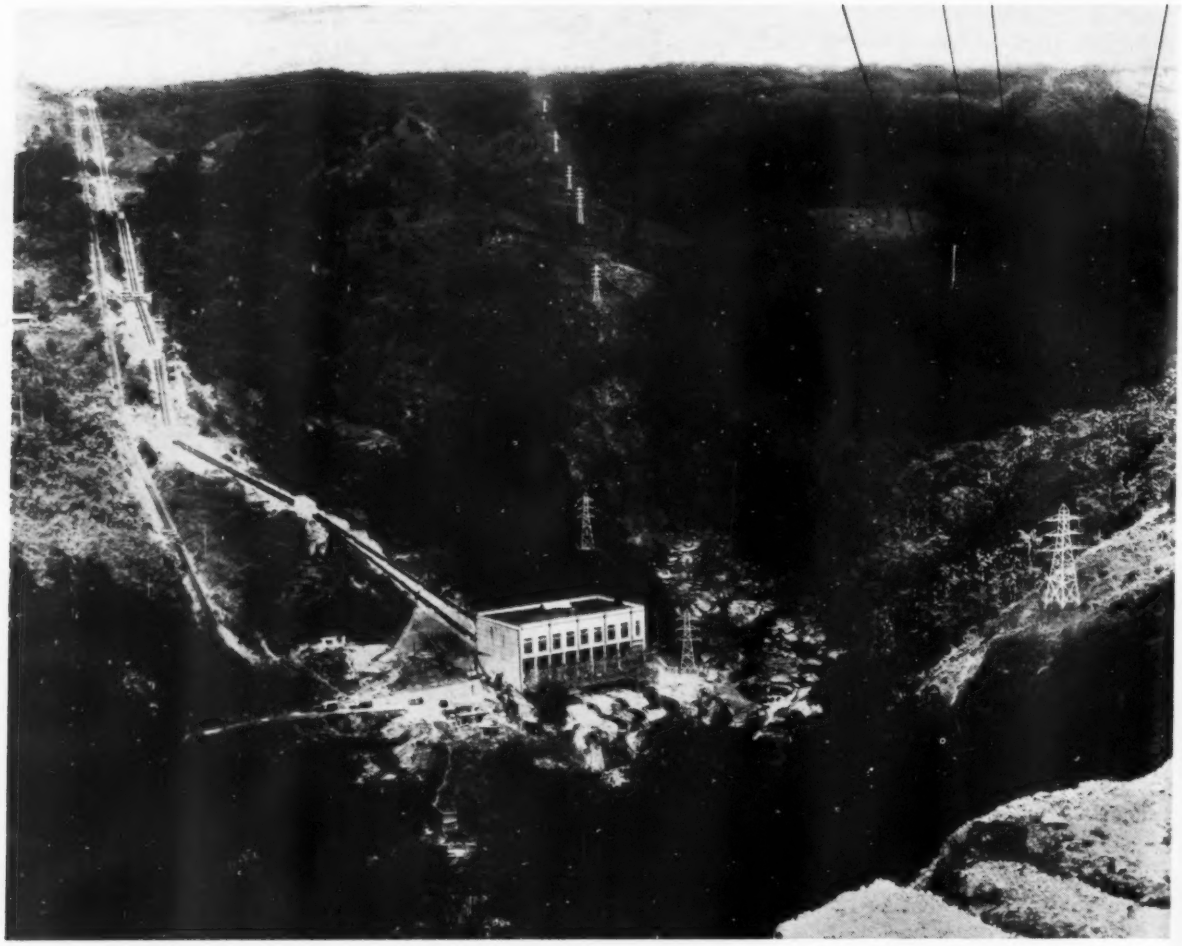
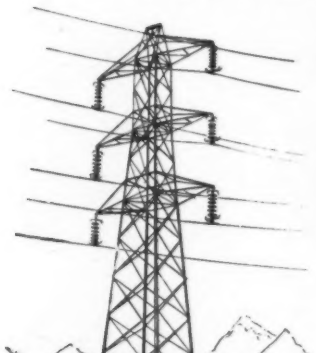


Across 78 MILES of country like this ...



BICC **OVERHEAD TRANSMISSION**

It's a tough job erecting lines and towers across the mountains, valleys and jungles of Ceylon. But BICC Engineers are used to work of this nature : they have recently completed the overhead transmission system for the first stage of the Laksapana Hydro-Electric Scheme. This comprises seventy-eight miles of double-circuit 66kV line to carry 25,000 kW of power to Colombo and Peradeniya.

Survey, siting, supply and erection of this transmission system were all carried out by the BICC group—who undertake similar installations anywhere in the World.

BRITISH INSULATED CALLENDER'S CABLES LIMITED
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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Minus and Plus

THERE are still factors in hydro-electric planning which seem to indicate that nature continues to hold a trick or two up her sleeve. Thus it has been necessary to record in these columns a number of instances where drought has caused either complete cessation of supply of electricity from hydro-electric plants with consequent severe interruption to the industrial and domestic life of the communities which they serve, or else of severe restriction having to be placed on the supply of electrical energy.

Against the onset of drought, only two weapons appear to be available. The first and greatest is that of increased storage and of combining the output of many diverse watersheds in such a way that one may bring compensation when another lacks rainfall. The second weapon, which is as yet in a somewhat doubtful infancy, is that of artificial rainmaking, principally attempted by seeding the clouds with such substances as the particles emitted by smoke generators creating silver-iodide crystals. So far, no results which bear the strictest scientific investigation as to their complete certainty of operation have been achieved; but nevertheless, as we mentioned in a recent article on this page, agricultural (and some hydro-electric) interests in the United States have evinced sufficient faith in the possibilities of artificial rain to enable them to give some financial support to those undertaking the experiments. Even so, we understand that a first-class legal battle is developing on the rights of rainmaking.

The second trick which Nature may play is to provide us with more water than we can use, and to tantalise us by the sight of great spillways over which enormous amounts of potential energy pass to waste. Very many dams contain spillways which for the greater part of the year are in full flood. Others, in fact, are designed in such a way that the majority of the water flow passes over the spillway in any case, and only a small proportion of the available energy is transformed into electricity. Here, the main difficulty in many cases is again one of storage, but storage of a different kind. It is so far impossible to store electrical energy on a large scale, and thus it is not economic to harness the whole of the output which may be available perhaps for nine months in the year from a particular development, since there is no way, save perhaps expensive pumped-storage schemes possible only in suitable terrains, of employing the energy which would be generated if the plant were available at times when the load was insufficient.

Two factors may cause a material alteration in this state of affairs. First, the very great rise in the use of electricity by the metallurgist and the chemical engineer may mean that it is not only economic, but imperative, to install electro-chemical plants near waterfalls, to use up every available drop of water, even if severe seasonal fluctuations are inevitable. Secondly, the electrical storage problem may be solved when the fuel cell has been fully developed into a commercially applicable and fully reliable device. But this time is obviously many years ahead.

Another aspect of superabundance of water, however, is that of damage by flooding. Many multi-purpose water-control schemes are initiated with the control of flooding as their prime purpose. But it is evident, from the number of reports which we receive from time to time of severe floods which not only affect vast areas of agricultural land but which may, in addition, inundate the power station itself, that much remains to be done by way of controlling water flow under flood conditions. As an example, the important hydro-electric station concerned with the Tarraleah development on the River Nive in Tasmania, where 126,000 h.p. is installed, was put out of commission for a brief period recently when the floodwater actually encroached on the turbine floor. Fortunately, little damage was done. The construction of the Clark Dam at Butlers Gorge will improve the storage position at Tarraleah and may well prevent the occurrence of such an alarming incident in the future.

The caprices of Nature add difficulty to every form of hydro-electric development, whether by creating

droughts or floods; but they also offer a perpetual challenge to the hydro-electric engineer, which makes his job all the more worth while.

New Zealand Prospects

IN a recent review of the power prospects of New Zealand, the Minister in charge of the State Hydro-Electric Department (Mr. W. S. Goosman) stated that it would take all-out effort to keep pace with the generally expected rate of growth of consumption of 10 per cent. per annum. Though there must inevitably be some falling off he did not visualise this happening within the next ten years. Besides the rise in general consumption, provision must also be made for special loads such as pulp and paper, fertiliser production, and railway electrification.

All these special loads are concerned with the North Island, and in the absence of a link with the South Island must be met from the resources there. To do so would necessitate the completion of the Waikato, Kaituna, and Rangitaiki hydro-electric schemes within the ten-year period and the provision of not less than 100,000 kW of steam plant. The problem would be relieved by the successful outcome of the investigations into the availability of sufficient geothermal steam at Wairakei to justify the installation of 20,000 kW of plant.

Argentine Power and Irrigation Prospects

NEWS from the Argentine is that an important combined power and irrigation development is nearing completion. This is the Escaba (Tucuman) project on the River Marapa, which is estimated to have cost 11,561,000 pesos; it will provide irrigation water for 55,000 acres, and also operate a 20,000 kW hydro-electric plant, working under a head of 135 metres. The dam was put into partial service at the end of October 1951 and it is hoped that shortly the whole project will be completed.

Developments in Finland

IN Finland, in common with many other countries, the stage has now been reached where the water power resources near at hand, in relation to the principal centres of industry and population, are within sight of being completely harnessed, and it has become necessary to reach out over considerable distances to bring in remote hydro-electric projects. News is now to hand of a number of new plants that are to be erected on the Kemi river, which flows into the Gulf of Bothnia, near the Swedish border. These five new stations will be the first plants on this river; and, together with another station on the Juminskujoki river, will give Finland a total hydro-electric output, it is hoped, of 6,485 million kWh per annum by 1956, which compares with a present output of 4,625 million kWh.

Italian Reconstruction

ACCORDING to statistics recently published the Italian power system in 1951 produced 28,818 million kWh (26,181 million from water power and 2,637 million thermally). This compares with 24,445 million kWh in 1950 (21,540 million hydro-electric and 2,905 million thermo-electric). In 1944 and 1945, as a result of aerial bombardment and other war operations, the output fell to 13,106 million and 12,365 willion kWh respectively. Between 1944 and 1945 destroyed or damaged generating plants representing a capacity of 1,366 MW were reconstructed and in the same period new hydro-electric plant totalling 1,781 MW and thermal plant of 187 MW were established.

River Lee Development

THE Electricity Supply Board, Dublin, has placed contracts for the main civil works in connection with the River Lee hydro-electric development. A French engineering firm, Société de Construction des Batignolles, will construct the dam, power stations and ancillary works at Carrigadrohid and Inishcarra, and John Paul and Company of Dublin will build the three major bridges and the new road diversions that will be necessitated by the flooding of about 3,500 acres of land to form the reservoirs for the two power stations. The larger of the stations will be built in the gorge at Inishcarra, about nine miles from Cork, and will have two generating sets of 15,000 kW and 4,000 kW respectively. Here the dam will have a maximum height of 173 ft. and will be about 813 ft. long. The reservoir created by this dam will provide storage for about 756 million cu. ft. of water and the existing water level will be raised about 100 ft. The second station at Carrigadrohid, about ten miles upstream from Inishcarra, will have an 8,000 kW generating set. The dam at this point will be about 70 ft. high and 350 ft. long, while the reservoir above the station will hold 900 million cu. ft. of water. Construction work will begin shortly and the scheme will take about four years to complete. The estimated output is 80 million kWh per annum.

A Canadian Low-Head Plant

IT is significent that Canadian engineers are now having to develop low-head projects which only a few years ago would not have been considered economic. For example, the MacArthur Falls on the Winnipeg River, which is the only undeveloped hydro-electric site in the Manitoba section of the water shed, is now to be harnessed, the Manitoba Hydro-Electric Power Board having already awarded the contract for the turbines. This has been placed with the Dominion Engineering Company of Montreal who are to supply eight 10,000 h.p. turbines to operate under a 23 ft. head. The dam will be 6,100 ft. long. The cost has been estimated at $22,000,000, and it is hoped that the plant will be completed in late 1954.

East African Demand

IN a recent address in which he discussed the increase in the use of electricity in East Africa, Major C. M. Taylor, chairman of the East African Power and Lighting Co. Ltd., dealt with some of the problems of keeping pace with the demand. He stated that two 500 kW gas turbines for Nairobi should have been in operation in January and August last year, but the first was not now likely to be in service before August 1953. Two 2,500 kW water turbines for the Wanjii scheme would also be available early in the year. Among new projects was the Lake Tana hydro-electric scheme for which a contract for 8,000 kW

had recently been concluded. At the end of 1951 a start was made by the company's engineers on extensive ground surveys to supplement the work previously carried out on the Seven Forks project. This scheme would yield some 80,000 kW under normal operating conditions.

In Tanganyika territory, a 5,000 kW extension had been held up by delays in the delivery of the necessary hydro-electric plant, while bulk supply to Mombasa from the Pangani Falls station had to be curtailed owing to the increasing local demand. Sales of the Company and its subsidiaries totalled 134·5 million kWh in 1951 as against 109 million kWh in 1950. Local disturbances in Kenya had not had an adverse effect on the business, but steps had been taken to guard the properties in the affected areas.

Power for East Quebec

WORK will begin early this year on the 100 million dollar Quebec Hydro-Electric Commission project to serve the expanding industrial needs of Eastern Quebec. The announcement was made recently by Premier Duplessis, who said the project had been described as the largest new hydro-electric development ever undertaken in Quebec. The plans involve the construction of a one million h.p. plant on the Great Bersimis River, in wild country nearly 85 miles north of Forestville; a dam 200 ft. high and 2,500 ft. long at the mouth of Lac Casse, fifteen miles north of the power plant, creating a reservoir covering an area of 260 square miles; and a tunnel eight miles long and 36 ft. in diameter, in which the water of the Bersimis will fall 870 ft. to the turbines. Four thirty-one mile cables will be laid across the St. Lawrence River.

Swedish Development Programme

IN Sweden, the continued development of water power resources and the extension of the transmission network are progressing rapidly. The Swedish State Power Administration, which is responsible for half of all the new hydro-electric power developments of the country, is planning to invest one million Swedish crowns each working day during the budget year 1953/54. Of the large hydro-electric projects which are now in course of construction, the Kilforsen power station is scheduled to go into operation next year. This station will contain three units of a total capacity of 240 MW, and the annual power production will amount to 1,200 million kWh. An additional 1,000 km of transmission line of the 380 kV network is also approaching completion.

In addition to these developments it is intended to start work on four new hydro-electric power plants on the Ume älv. This river, which flows into the Gulf of Bothnia, has hitherto only been developed to a small degree. The power sites are located in the upper and lower reaches of the river. Three power stations, having a total maximum capacity of 195 MW, are to be constructed on a stretch of 35 km of the upper part of the Ume älv. The energy production of the plants is estimated at 1,000 million kWh per annum. Each station will utilise a water flow of 275 cu. m. per sec. The construction costs are estimated at 175 million Swedish crowns. Work will begin this year and the stations are scheduled for operation in 1957-58.

The fourth new power plant on the Ume älv will be built near the mouth of the river. The work on this project will also start this year and part of the station is planned for completion in 1959. The head to be utilised amounts to 75 m. and if—but this is not yet decided—the total head will be developed in a single plant, this station will be even larger than Harsprånget, Sweden's greatest hydro-electric power installation up to the present. The new power station will have a maximum capacity of 360 MW and an annual output of 2,200 million kWh. It will utilise a water flow of 600 cu. m. per sec.

Rumanian Expansion

ONE thousand seven hundred MW of electric power is scheduled for installation by the end of 1955 in Rumania. By far the biggest hydro-electric project will be one named after Lenin and now under construction on the swift-flowing Bistritza River in the mountainous north-east of Rumania. It is the main work of the electrification plan and the station will have a capacity of 210 MW. Its turbines will distribute power to many industries, including some to be set up under the five-year plan, at the rate of 430 million kWh a year. This attempt to harness the power of the Bistritza began about two years ago. It involves the creation of an artificial lake 300 ft. above the level of the present valley with a capacity of 1,000,000 cu. m. The tunnel, now being driven from both ends, will carry water from the lake to the turbines which will be about 150 ft. below the water level. Eventually the storage lake will provide irrigation for over 7,000,000 acres of land in southern Moldavia and the north Baragan steppe. The building site is one of the largest in Rumania at the present time and large quantities of equipment are arriving in a steady stream from the Soviet Union as well as from industrial plants in Rumania. The transformation that will result from the ten-year electrification plan can best be appreciated against the background of Rumania's power position as it was even as recently as the end of 1950. The capacity of the then existing power stations was 740 MW of which only 600 MW could be used. Operation was extremely uneconomic — over six hundred stations with an average installed capacity of only 1,230 kW. Less than 30 per cent. of the country's population lived in areas provided with electricity.

With its enormous waterways and large lignite deposits, Rumania has a considerable energy potential to be developed. The potential of water power, it has been estimated, is something like 5,650 MW with a possible production of energy in normal years of 27·2 billion kWh. Government policy, however, is to prevent too great reliance on hydro-electric stations because of the enormous problems of irrigation and navigation which are likely in years of drought. The programme for the ten years programme provides for the construction of 13 thermal electric stations, extensions to five thermal electric stations, and the building of 24 hydro-electric stations.

Machinery Lloyd

Odhams Press Limited has acquired the whole of the share capital of Continental & Overseas Organisation Limited, the Company owning "Machinery Lloyd." No fundamental changes are contemplated in the conduct of the journal. Mr. Geo. L. Layton will remain Managing Director.

Lining the Bowland Tunnel

Novel and expeditious methods are being used to line the Bowland Forest tunnel which will carry water from Haweswater to Manchester. Although this tunnel is for water supply, the methods employed are of direct interest to hydro-electric engineers.

IN our January 1951 issue we published an article* describing the methods and equipment employed to drive the Bowland Forest tunnel to carry water from Haweswater in the English Lake District to Manchester. The tunnel forms part of a notable water-supply scheme, and the interest to engineers lay in the success with which the tunnel was being driven in particularly difficult ground. Rock conditions were so unstable that extensive use had to be made of steel supports, and frequent resort had to be made to forepoling or some equivalent procedure. Water was a second major working hazard and needed

* "Notable Water Tunnel" by C. F. Grundy, M.Eng., M.I.C.E., WATER POWER, January 1951, page 24.

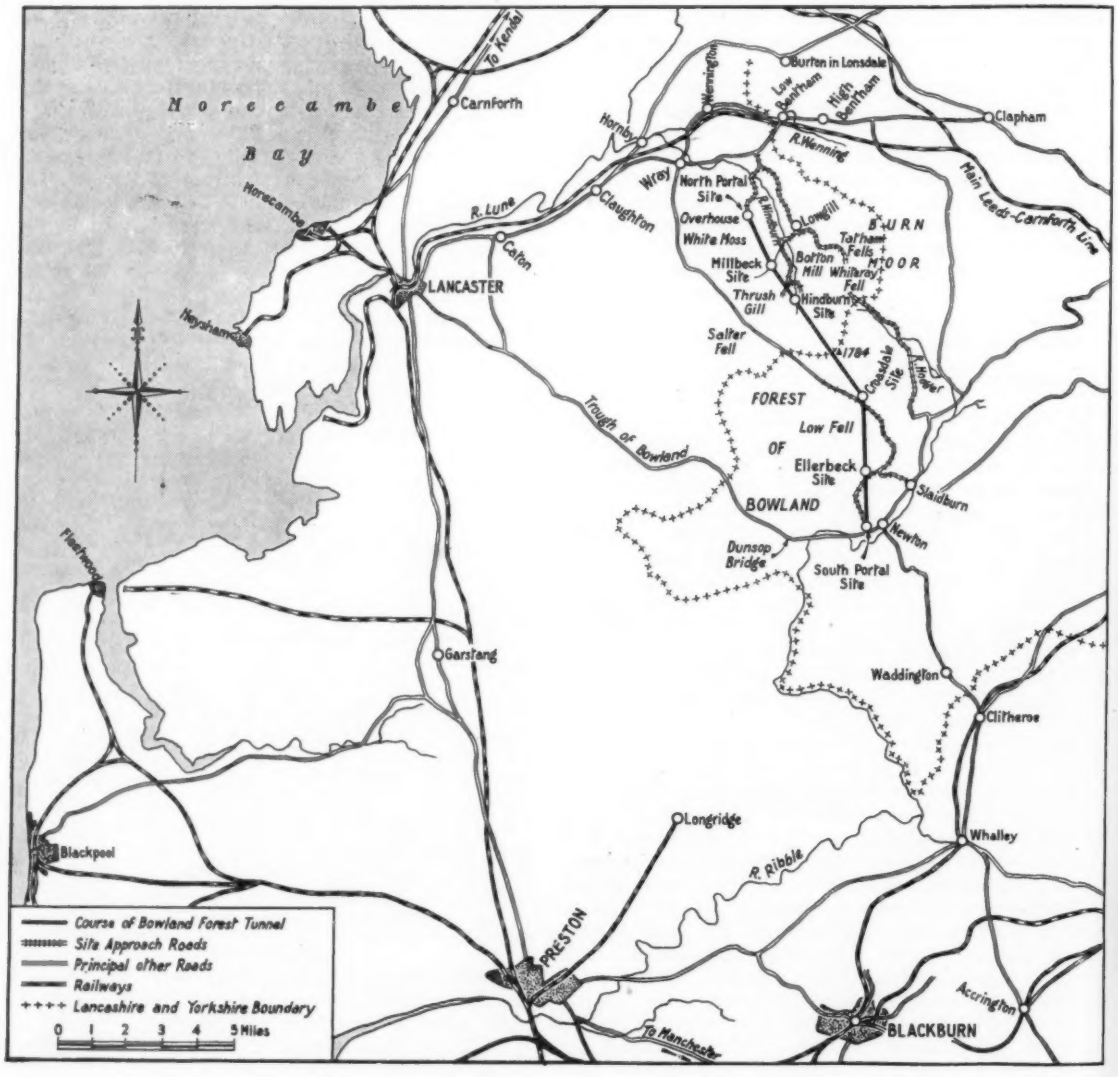


Fig. 1. Map showing location of Bowland Forest tunnel

special provision throughout the driving operation.

Since the previous article was published the driving has been completed and the tunnelling procedure proved so effective that this part of the work was finished two months ahead of schedule. Equally satisfactory progress is now being made with the concrete lining, and the lining procedure is of such direct interest to engineers concerned with tunnel construction for hydro-electric schemes that we make no apology for devoting a further article to this contract.

The Haweswater Scheme

The Haweswater scheme comprises the damming of Haweswater in the Lake District and conveying the water in a closed aqueduct a distance of 73 miles to Manchester. Flow will be entirely by gravity. Steel pipes will be used for those sections beneath the hydraulic gradient, while the portion at the hydraulic gradient will be in tunnel or in concrete-lined cut and cover. Altogether about 30 miles will be in tunnel, having a gradient of 1 in 3,000.

The first nine miles of the aqueduct was constructed in the 1930's to enable the Haweswater reservoir to feed the Thirlmere aqueduct. The scheme is now being pressed to completion, and it is expected that the Haweswater aqueduct will be finished in 1954.

The contract with which we are concerned covers a length of 54,000 ft. (about 10¼ miles), all except about 1,000 ft. of which is in tunnel. In Fig. 1 we reproduce a map from Mr. Grundy's article showing its location. The tunnel runs roughly north to south under the Bowland Hills, and has been driven from the north and south portals, two shafts at Croasdale and Ellerbeck, an adit at Hindburn, and a short open cut at Millbeck.

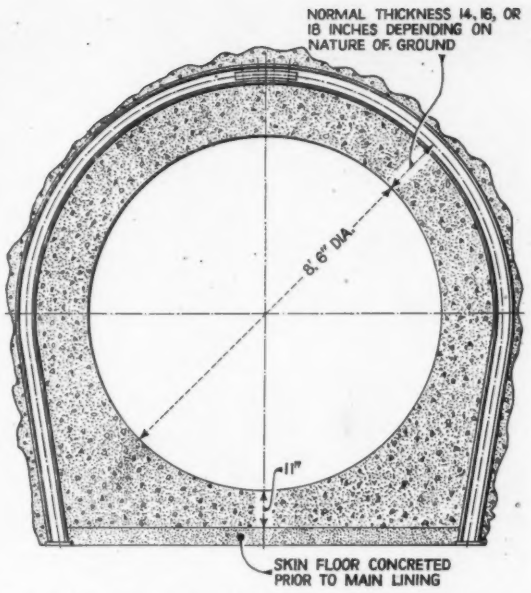


Fig. 2. Typical section through Bowland Forest tunnel

Fig. 3. Pressweld placer and ancillary gear, assembled on the surface

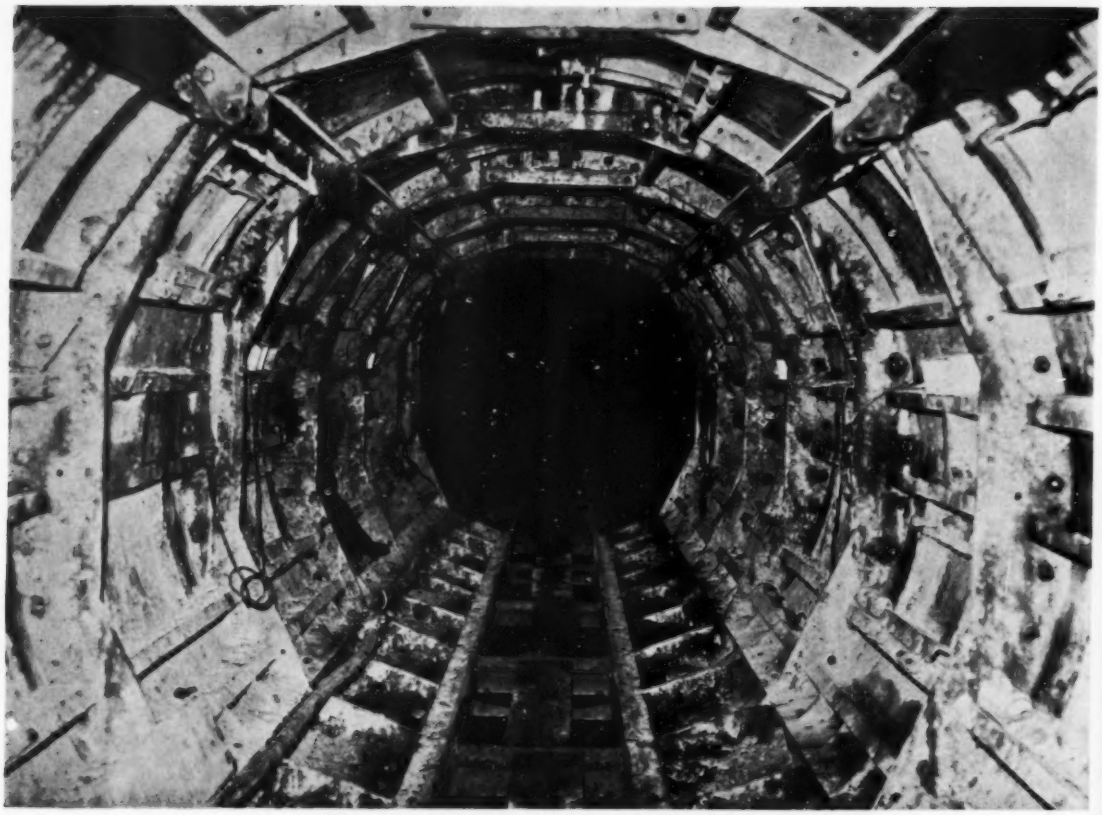


Fig. 4. Trailing end of shutter before striking

The Tunnel Lining

A typical section through the tunnel is given in Fig. 2, which shows that the finished bore will be circular and of 8 ft. 6 in. diameter. Steel supports are being left in place, and the concrete lining has a nominal thickness of 14, 16 or 18 in. according to the nature of the ground. As soon as any particular drive was completed, the floor was mucked out and a concrete skin floor was put down. On this floor a 2 ft. gauge track with 30 lb. rails was laid to convey the traffic for placing the main lining.

The geology of the district varies considerably, the rock ranging through limestone, conglomerate grits, and shales, but the use of these rocks from tunnel excavations for aggregate production was not possible. Fortunately a sandstone deposit was available near the Croasdale shaft, and a quarry has been opened out to provide both aggregate and sand. As a quarrying proposition it is not ideal, for the ground is broken and an excess of undersize is made, but these disadvantages are outweighed by the proximity of such suitable material to one of the most convenient feed points to the tunnel.

The Croasdale shaft has been stripped of its hoist and headgear and equipped with bins for aggregate.

Fig. 5. Train of transit cars being loaded with concrete at central mixing station

Fig. 6. Leading end of shutter awaiting crown and side sections

sand and cement. A batching and mixing plant is located at the bottom of the shaft feeding rakes of transit cars. Concreting commenced at the north portal and at the time of writing is proceeding towards the Croasdale shaft. When this has been reached the equipment will be turned round and the southern section of the tunnel will be lined, proceeding from the south portal to the shaft.

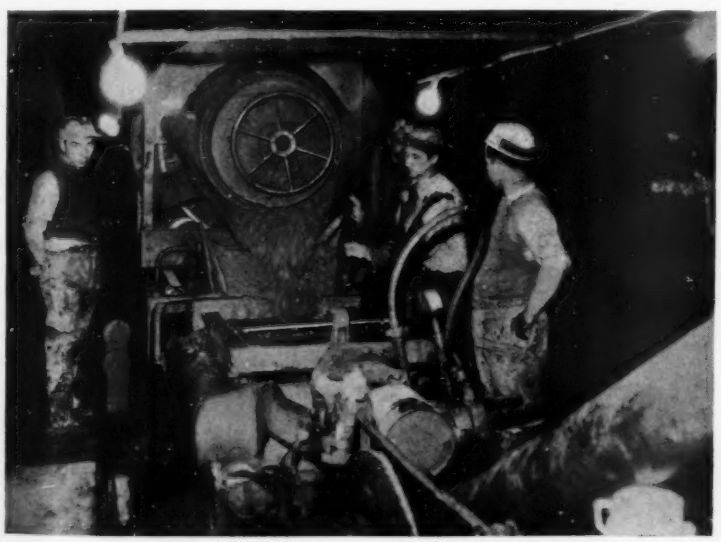


Fig. 7. Transit car drawn up on loading platform being discharged into Pressweld placer

The Quarry and Crushing Plant

Owing to the broken character of the deposit it is not feasible to adopt the deep-drilling technique, and the quarry is worked in 25 ft. benches. Two 15 BE shovels remove the soil after blasting and transfer it to a fleet of three 4½ cu. yard Aveling Barford quarry dumpers which convey it to the primary crushing plant. This plant is located at the foot of the quarry, and advantage has been taken of the slope of the hill to secure gravity flow as far as is practicable. Two concrete hoppers built on the hillside immediately below the dumper road receive the spoil and feed it to the two primary crushers by means of Locker Traylor vibrating feeders which are under the control of the crusher attendant at his working place. A 2 in. grizzly screen is incorporated in each feeder, and quarry dross is removed by a

Fig. 8. Traffic end of the movable platform, assembled on the surface

16 in. cross belt conveyor to a refuse tip.

The primary crushers are of the jaw type, one being a new Parker 30 × 18 in. and the other a Goodwin Barsby 30 × 20 in. machine. These machines reduce the rock to below 4 in. and discharge to a common 30 in. horizontal belt conveyor which feeds the loading bin of an aerial ropeway. This ropeway is of the single-rope type, 1,600 ft. long and is provided with 18 15-cwt. buckets. Its function is to transfer the stone to the secondary crushing plant near the top of the Croasdale shaft, and owing to the favourable gradient it operates by gravity except for starting.

At the shaft site the ropeway discharges to a 120 ton unloading bin from the bottom of which a 24 in. belt conveyor, supplied through a vibrating feeder, transfers the stone to the secondary crushers, a scalping screen being interposed to bypass material below $1\frac{1}{2}$ in. direct to the screens.

Two types of secondary crusher have been installed —a Nordberg 2 ft. cone crusher and an Ajax hammermill—so that advantage can be taken of their differing characteristics to control the grading of the final product.

A bucket elevator then lifts the crushed material to the screens, which are of the high-speed vibrating type and make $1\frac{1}{2}$—$\frac{3}{16}$ in. and sand (minus $\frac{3}{16}$ in.). Material over $1\frac{1}{2}$ in. is returned to the Ajax machine for recrushing. The sized products fall to storage bins from which a 24 in. belt conveyor transfers either size as required to the shaft.

Shaft Storage and Batching Plant

Croasdale shaft is 18 ft. in diameter and 270 ft. deep. As already mentioned it has been stripped of its winding equipment and has been compartmented to take aggregate, sand, and cement. The 24 in. conveyor just mentioned leads to a swivelling chute which discharges to aggregate or sand compartments as required. Cement is brought to the site by lorry in bulk and is tipped direct into the cement compartment. This takes the form of a 6 ft. diameter steel tube, the mouth of which is hooded and is kept closed in wet weather. Water from a surface supply is also piped down the shaft to a storage tank.

The various storage hoppers terminate 45 ft. above the floor of the tunnel, and in the remaining shaft space is housed a Winget weigh-batching and mixing plant. Separate batching hoppers are provided for aggregate, sand, cement and water; each hopper is mounted on its own weigher, which is equipped with a large pointer by means of which the weight of the batch can be determined accurately. The individual batches are dropped into a 2 cu. yard tilting-type drum mixer from which the mixed concrete is discharged alternately to one or other of two transit-car loader hoppers. By this means mixes can be held in readiness, and a rake of cars can be loaded without being held up for the mixer. The loading station is depicted in Fig. 5.

All the operations of batching, mixing, and discharging to the loader hoppers are carried out by one man on the batching floor. A second man superintends the discharge of concrete from the loader hoppers to the transit cars.

Underground Transport and Control

The mixed concrete is conveyed to the placing point in Ransomes & Rapier transit cars which are nominally of 2 cu. yard capacity, but can accept $2\frac{1}{2}$ cu. yard. They are of the non-tilting drum type with end discharge, and each car is fitted with its own electric motor and trailing cable to effect the discharge. Fifteen of these cars are in service, made up in five trains of three cars each.

To avoid locomotive dead time at the terminals the routine is to pick up the waiting train, leaving the train just brought to the terminal to be charged or discharged as the case may be. By this means only four locomotives are needed to operate the five trains. A larger number was needed during the driving operations, and in view of this two alternative fleets of locomotives are available, one consisting of four Ruston 40 DLU diesel locomotives and the other of four Hudwell Clarke 12 h.p. battery locomotives.

We have already given particulars of the track, and it remains to add that it is single-line except for three passbyes between Croasdale shaft and the Hindburn adit—a distance of four miles. The adit track is also used as a passbye.

Operations have been greatly assisted by a system of traffic control which was devised by the contractors and has worked admirably. It is based on a speech-

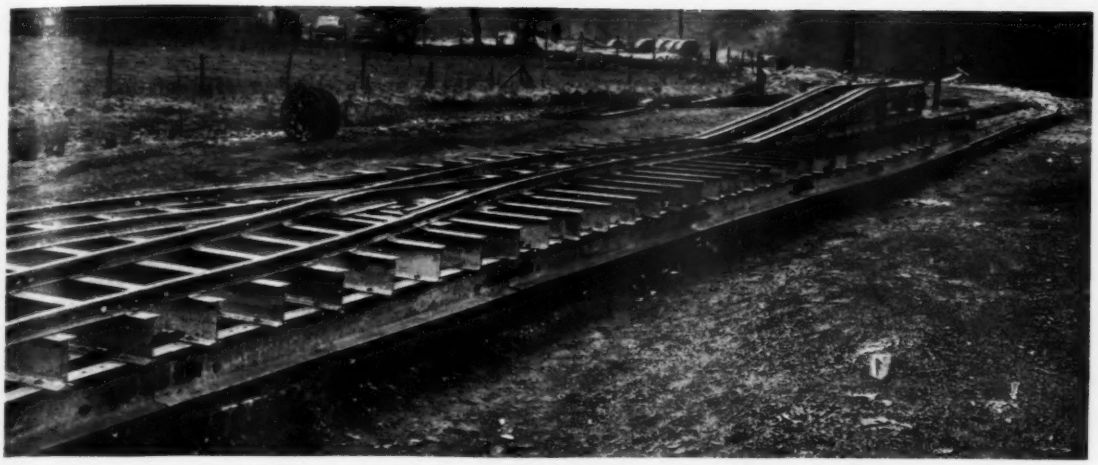


Fig. 9. Placer end of the movable platform, assembled on the surface

diffusion system with call-back facilities, and is in the hands of a traffic controller, seated in an underground control room. Loudspeakers and microphones are located at all strategic points—terminals, passbyes, adit, substation, engineer's office, etc.—those in the tunnel being "flagged" with coloured lights.

The traffic controller has a mimic diagram on which each train (each has a distinctive designation) is represented by a movable slider. Each man in the tunnel is also represented by a tab placed on the diagram in accordance with his position in the tunnel. All movements, both of trains and of men, must be reported back to the controller at every control point, and it is his function to give instructions as to what movements are to be carried out or permitted.

The system is also invaluable in coping with those emergencies and lesser eventualities which disturb the routine of any contract, for the traffic controller acts as a co-ordinating centre, advised if necessary over the loudspeaker system by the engineer.

When we visited the working the control room was in a small annexe to the tunnel near the Hindburn adit, but as the lining was approaching the adit, arrangements were being made to transfer the control room to a blind heading at the base of the Croasdale shaft. In this new position no further disturbance will be necessary as the Croasdale shaft forms the terminal point of the lining operations from both the north and south portals.

Lining Procedure

The lining operation is unique in Great Britain, for the Bowland tunnel is believed to be the first contract in this country in which the complete cylinder is being placed in a single operation. Placing is continuous, except for the week-end break, and is accomplished by a Pressweld placer in conjunction with a steel shutter which can be moved forward in sections.

The Pressweld placer and the associated equipment are carried on a movable platform, 250 ft. long, on a 6 ft. gauge track which is laid in advance of the platform. The platform is hauled along as required by a compressed-air winch mounted on the placer assembly. At the traffic end of the platform is a ramp carrying a 2 ft. gauge track which registers with the tunnel track. A second compressed-air winch on the placer assembly hauls a train of full transit cars up this ramp to a double-track section where empty cars are worked past the fulls. At the placer end of the platform this double-track section reverts to single-track and passes up a second ramp leading to an elevated level section adjacent to the placer. Full cars are hauled up this second ramp one at a time, discharged into the placer, and returned to the empties track.

Figs. 8 and 9 are photographs of the two ends of the platform assembled in the open. It will be noticed that it has been made in 10 ft. sections to facilitate the initial transport to its working place and its subsequent reversal when lining begins at the south portal.

In Fig. 3 will be seen the section of the platform carrying the Pressweld placer assembly. The placer itself is on the left; the winch for handling the transit cars is towards the centre; behind is an air receiver, and at the far end is a cubicle carrying the electrical equipment. The equipment also includes an emergency compressed-air-driven lighting set. Fig. 7 shows a transit car being discharged into the Pressweld placer.

Compressed-air, water, and electrical mains are laid along the side of the tunnel, and flexible connections are taken off to the placer assembly.

Continuous placing has been made possible by the ingenious design of the shutter, which is such that a section can be struck at the far end, brought through the shutter, and erected at the placer end, all these operations being carried out while the placer is at work. The following description will be clarified by reference to the diagrammatic sketch, Fig. 10, and to the photographs reproduced in Figs. 4 and 6. The shutter is 200 ft. long in 5 ft. sections, and is moved in 20 ft. lengths. For setting and striking purposes each length is divided into four parts—invert, two sides, and crown. The two sides are hinged to the crown and mate with the invert on slightly sloping faces, all four parts being securely bolted together after they have been set. A 2 ft. gauge track is incorporated in the invert shutter, and sides and invert are fitted with doors through which the concreting can be inspected and hand punning carried out.

The method of handling the shutter may best be

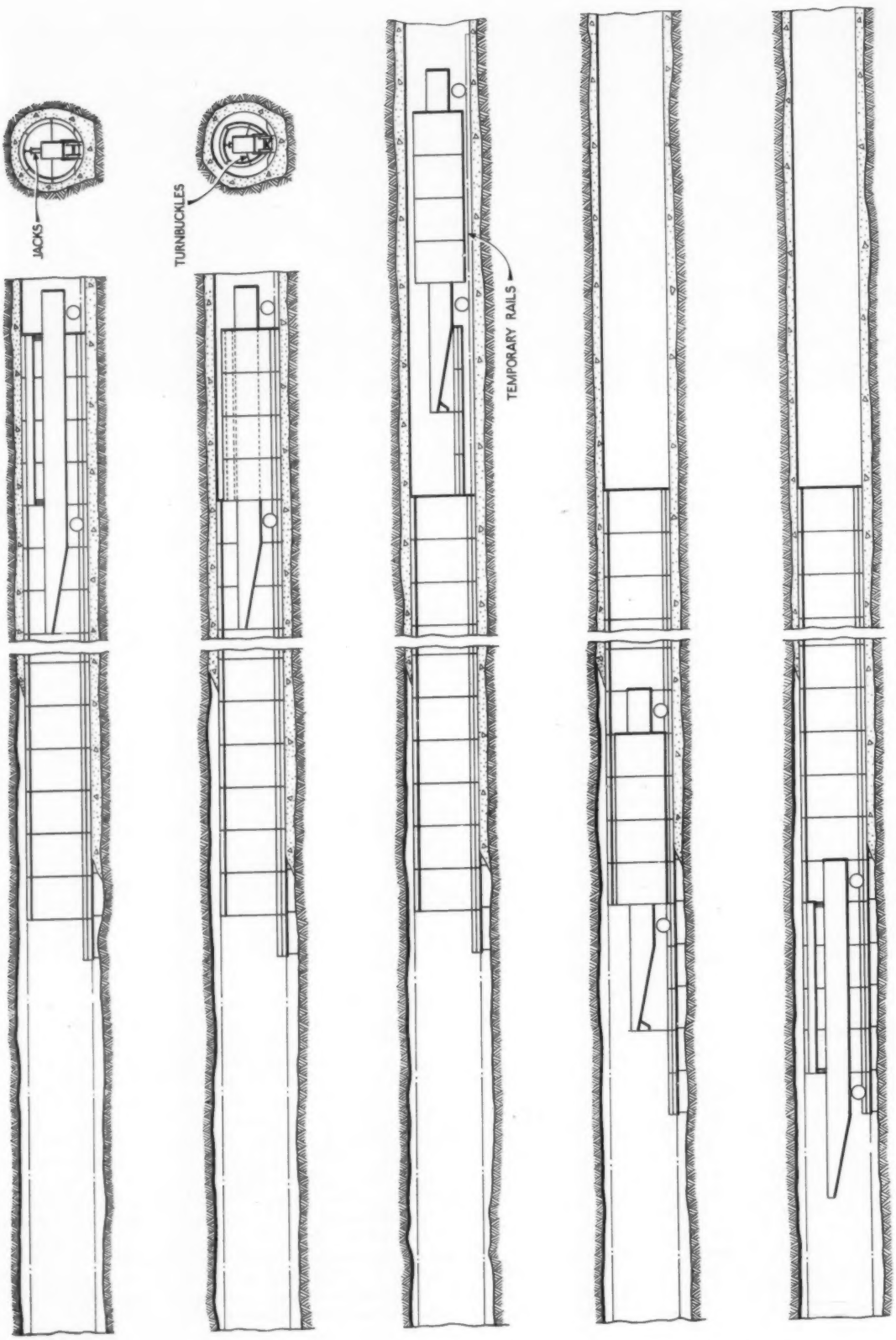


Fig. 10. Diagrammatic sketch showing the method of advancing the shuttering

explained by considering first the striking of the rear section and then its transfer to the front. All these operations are carried out by a transporter, which runs on the 2 ft. track inside the shutter and takes the form of a wheel-mounted box girder with an overhanging boom on the end towards the placer.

To strike the rear 20 ft. length of shutter, this transporter is run into the section, a beam is raised on screwjacks to take the weight of the crown, the fixing bolts are withdrawn, and the sides are drawn in by turnbuckles, coming clear of the invert shutter and hinging on the crown shutter. The entire shutter assembly is then lowered by the screwjacks until it is in a position to pass through the rest of the shutter.

It still remains, however, to pick up the invert, and to effect this a temporary track is laid on the invert of the completed lining immediately beyong the shutter. The transporter runs out on this track until the boom is over the invert shutter, which is then lifted by a tackle carried on the boom.

The transporter, carrying all four parts of the length of shutter, is then wheeled through to the forward end of the shutter, where the invert is first dropped into position. It is supported on adjustable legs and is aligned to surveyor's marks on the roof and sides of the tunnel and finally bolted to the standing shutter. The transporter is then brought forward over the invert, and the top and sides raised by the screwjacks and placed in position.

Rate of Progress

These methods have enabled a very high rate of progress to be maintained. When we visited the tunnel the haul from the Croasdale shaft to the placing point was about 4½ miles, and the length of lining placed during the previous week was 957 ft. This was a typical figure, and it was confidently expected that when the haul became somewhat shorter the figure of 1,000 ft. per week would be exceeded.

The method of placing the entire cylinder in one operation and of concreting continuously tends to good work because it reduces joints to the minimum. At the end of the week a wooden stop end is built, and no difficulty is experienced in picking up at the beginning of the following week. An inspection of the recently completed portion of the lining revealed a uniformly sound result requiring the minimum of making good.

Acknowledgments

We are happy to acknowledge the kind permission of Mr. Alan Atkinson, M.Eng., M.I.C.E., M.I.W.E., Engineer and Manager of Manchester Corporation Water Department, to visit the workings and publish this article.

The contractors for the entire construction of the Bowland tunnel are The Cementation Co. Ltd., Doncaster, and we are deeply indebted to that company's agent, Mr. J. Widdowson, A.M.I.C.E., who went to great trouble to take us over the workings and explain the procedure. The photographs accompanying this article were also kindly supplied by The Cementation Co. Ltd.

The consulting engineer responsible for the design of the shutter, the central mixing station, and of the concrete distributing and placing equipment is Mr. C. Parry, A.F.C., M.I.Struct.E., Lloyds Bank Buildings, Muswell Hill, London, N.10.

Fig. 10. Diagrammatic sketch showing the method of advancing the shuttering

Salmon and Hydro-Electric Schemes

In the course of an address to the Royal Institution of Chartered Surveyors given in London recently, Mr. Thomas Lawrie, General Manager of the North of Scotland Hydro-Electric Board, stated that one of the most interesting aspects of water-power development was its inter-relation with salmon fishing and the stock of fish. Hydro-electric schemes, he added, might affect the salmon in at least four important ways. If a dam was thrown across a river, arrangements must obviously be made for the ascending fish to surmount it. Secondly, if a reservoir flooded out the gravels which had previously been used by spawning fish, care must be taken either to see that sufficient alternative natural spawning was available or that a hatchery was provided. Thirdly, water might be taken away from its natural course through a tunnel to a power station either far downstream or even in another valley. If the river thus depleted used to provide good spawning, then compensation water must be let down so that the fish life could be maintained. Finally, there was the problem of enabling the young salmon (smolts) to migrate downstream to the sea.

To enable salmon to surmount dams, fish passes were provided, these having been gradually developed from the simple "slap" in a mill dam, through the staircase or ladder of pools to the modern passage way invented by Mr. Borland of Kilmarnock, four of which passes were now being built at the Torr Acilty, Luichart and Meig dams of the River Conon scheme and at the Garry dam.

As a further measure to preserve the stock of fish, hatcheries were being built, one for the River Garry in Inverness-shire and one for the tributaries of the River Conon in Ross and Cromarty. The fry, he explained, when hatched out would be distributed widely in the neighbouring river and loch so that they would have the best chance of finding food and avoiding predatory birds and fish. In two other cases—on the River Conon in Ross and Cromarty and the River Lochay near Killin in Perthshire—the Board had undertaken to open up water-falls at present impassable to salmon so as to provide access to new stretches of river for spawning, thus making up for stretches elsewhere which had been submerged by new reservoirs. An attack was also being made on predatory fish, last season the catch having amounted to 1,289 pike, 1,017 eels and 21,329 perch.

Geo. Kent Ltd., Canadian Company. A company has been formed and has commenced operations in Canada under the title of Kent-Norlantic Limited, at Horner Avenue, Toronto 14. This organisation takes over from the parent company, George Kent Limited, the responsibility of marketing throughout Canada, Kent industrial instruments, certain other products, and the Norlantic range of domestic and industrial water and steam meters. Arrangements are being made for the manufacture and assembly in Toronto of the Norlantic range and other products, and for stocks to be held to meet Canadian delivery requirements both of new equipment and spares. The company will operate a comprehensive organisation to cover after-sales service.

Alberta's Water-Power Resources

We describe the main river systems of Alberta, and give a summary of existing and potential hydro-electric developments. Special reference is made to recent developments on the Bow River and its tributaries and to the work of the Alberta Power Commission.

THE Canadian Province of Alberta is rich in natural resources. Much of it lies in the great prairie belt, and agriculture naturally forms one of Alberta's most important industries. Ample fuel resources are at hand, in the form of coal, oil and natural gas, but one of nature's most abundant gifts is water. The Rocky Mountains form the western boundary of the Province, and many of the great Canadian river systems rise in or traverse the territory. When suitably regulated, these rivers will provide an almost unlimited supply for irrigation, power production, and for industrial use in pulp mills, chemical plants, refineries and so forth.

Surface-water supplies in Alberta may be roughly classified into three groups. First come the permanent streams which rise in the mountains and are constantly fed by melting snow and ice. Together with their tributaries they provide large volumes of water and form the reliable sources of supply. They flow swiftly through the foothills, practically on top of the land, and in these regions can be readily diverted for irrigation or power. As they reach the prairie, however, they cut down into deep valleys and are not so amenable to gravity diversion, whereas pumping to prairie level is usually not economical. As is to be expected from their origin, the run-off of these rivers is subject to wide seasonal variation, being greater in the early summer, so that extensive headwater storage is necessary both for power and for irrigation.

Secondly there are the smaller and less permanent foothill or prairie streams. These can be used to irrigate small patches of land, but are used mainly for municipal, industrial and domestic purposes.

Thirdly there are miscellaneous streams and bodies of water of a sporadic nature, which may go dry in the summer, but which, although small individually, are very important in the aggregate. Extensive use is made of them for flood irrigation during the spring, and water for domestic, stock-watering and other purposes can be conserved for use during the whole year by means of dams and dugouts.

Main Drainage Basins

Practically the whole of the supplies are contained in the following drainage basins, reading from south to north: Milk River; South Saskatchewan River; North Saskatchewan River; Slave, Peace and Athabaska Rivers; and Hay River.

The Milk River runs partly in Canada and partly in the United States, and is of great importance to both countries for irrigation. The area of the drainage basin above the eastern international crossing is 2,514 sq. miles, and the average annual run-off, estimated for the period 1920-1940 inclusive, is 116,000 acre ft.

From the standpoint of power generation the South Saskatchewan basin ranks high in importance. Its tributaries, together with their run-offs, are listed in Table I. All of these rivers, together with their tributaries, join in Alberta to form the South Saskatchewan River. The stream then flows into Saskatchewan where it is joined by the North Saskatchewan some 40 miles below Prince Albert to form the Saskatchewan River, which flows to Lake Winnepeg and thence by the Nelson River to Hudson's Bay. The estimated annual run-off at the Alberta-Saskatchewan boundary is 5,752,377 acre ft., derived from a drain-

TABLE I. TRIBUTARIES OF THE SOUTH SASKATCHEWAN RIVER.

River	Point of Estimation	Drainage area sq. miles	Average Annual Run-off	
			acre ft.	acre ft. / sq. mile
Waterton	Stand-off ...	695	638,000	917
Belly	Stand-off ...	477	274,000	574
St. Mary	Lethbridge ...	1,328	671,044	505
Oldman	Mouth	9,705	2,796,346	288
Little Bow	Mouth	1,745	22,976	13
Highwood	Mouth	1,550	550,533	355
Bow	Mouth	9,770	2,687,769	275
Red Deer	Mouth	18,160	1,546,000	85

TABLE II. TRIBUTARIES OF THE NORTH SASKATCHEWAN RIVER.

River	Point of Estimation	Drainage area sq. miles	Average Annual Run-off	
			acre ft.	acre ft. / sq. mile
Clearwater ...	Mouth	1,214	698,000	575
Brazeau	Mouth	1,930	not available	not available
Sturgeon	Mouth	1,295	77,150	59
Vermillion	Mouth	2,323	not available	not available
Battle	Alberta boundary	10,230	263,803	26
"	Mouth	11,850	311,000	26

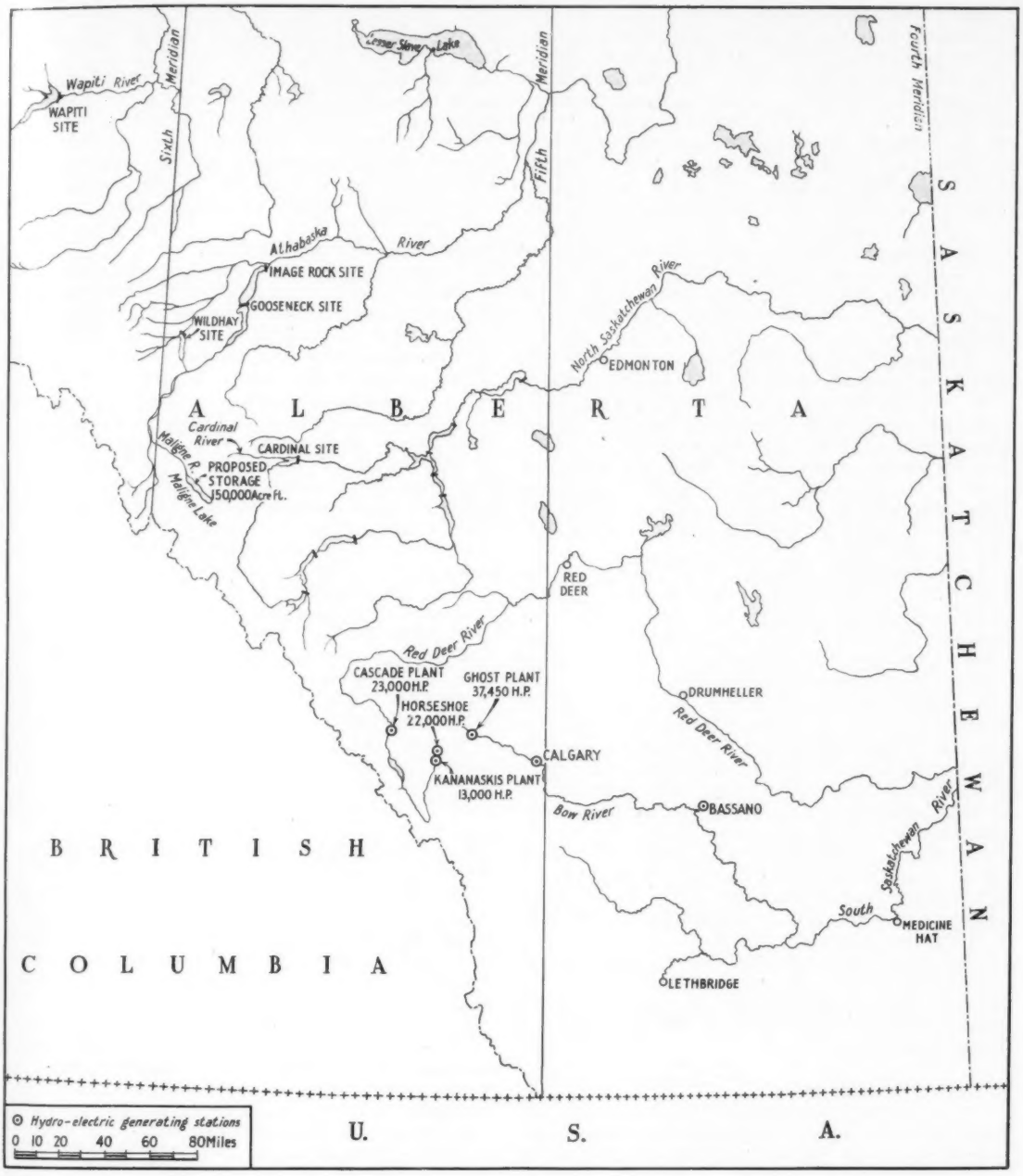


Fig. 1. Sketch map of Alberta showing existing hydro-electric and thermal stations and possible sites for new stations

age area of 20,600 sq. miles, or 141 acre ft. per sq. mile; above its mouth the corresponding figures are 7,492,000 acre ft., 53,325 sq. miles, and 140 acre ft. per sq. mile.

Of the various tributaries of the South Saskatchewan the most important both for power and for irrigation is the Bow River; indeed, from this standpoint it is the most important river in Alberta, and it has already been partly developed for both purposes. Its main tributaries are the Cascade, Ghost, Spray, Kananaskis, Elbow, Sheep and Highwood Rivers. There is very little inflow below the mouth of the Highwood, practically the whole of the run-off coming from the mountains and foothills.

Another tributary of the South Saskatchewan that offers many possibilities for power and irrigation development is the Red Deer, and several sites have been investigated.

The North Saskatchewan rises in Glacier and Waterfowl Lakes just to the east of the Great Divide, and its main tributaries are listed in Table II. At the Alberta-Saskatchewan boundary the area drained by the North Saskatchewan is 16,200 sq. miles, the average annual run-off 5,927,000 acre ft., or 365 acre ft. per sq. mile. At its confluence with the South Saskatchewan the corresponding figures are 46,100 sq. miles, 6,234,000 acre ft. and 135 acre ft. per sq. mile. Important hydro-electric potentialities exist in this basin, and a large number of sites are under survey.

The Athabaska River rises in the Rocky Mountains and flows in a north-easterly direction for almost 1,000 miles to Lake Athabaska, forming the most southerly portion of the Mackenzie River basin. Large lakes in the upper reaches tend to regulate the flow, so that spring floods, although they occur, are not so severe as for most mountain and foothill streams. The main tributaries of the Athabaska are the MacLeod, Pembina, Lesser Slave, and Clearwater Rivers. The drainage area at Athabaska is 29,642 sq. miles, and the average annual run-off 10,600,000 acre ft. or 358 acre ft. per sq. mile. At the mouth the drainage area is estimated to be 59,480 sq. miles and the average annual run-off 16,908,900 acre ft. or 284 acre ft. per sq. mile.

There are natural storage sites at the head of the river and a number of good dam sites below, and the Athabaska has for some time been considered to offer excellent opportunities for a comprehensive water-power scheme similar to that on the Bow River. A number of sites have been investigated.

The main outlet from Lake Athabaska is the Rocher River, which joins the Peace River to form the Slave River, flowing into Great Slave Lake. The Peace is the largest and longest tributary to the Slave River, and its most important tributary is the Smoky River, which in turn is fed by the Wapiti and the Little Smoky. There are some power sites on the Peace River system which may eventually become attractive although their location is remote. On the Slave River power potentialities exist at Smith Rapids, but here again the remoteness of the location is a barrier to development.

Hay River forms practically the northern limit of the prairie country. It rises in Alberta, issues into British Columbia and returns to flow into Hay Lake, whence it flows north-eastwards to discharge into Great Slave Lake.

Historical background

By an Act of Parliament of 1884 all surface waters were made the property of the Crown in the right of the Dominion. In 1923 many Alberta citizens were of the opinion that Government operation of power generating facilities similar to those obtaining in Ontario should be investigated, and in 1924 the Ontario Hydro-Electric Commission was invited to make a survey of the economical power sites that might be developed in Alberta and the probable consumption of electricity. In its report the Commission strongly recommended that the power resources of Alberta should be developed and operated as a single unit, whether by private interests or by Government agency. Much attention was paid in the report to the potentialities of the Bow River, and since then Calgary Power Limited has been largely responsible for its development.

In December 1929 an agreement was signed whereby the water resources of Alberta were transferred from the Dominion to the Province.

Rural electrification formed an important element in the plans for the development of the province, and in 1944 the Alberta Research Council submitted a comprehensive report in which it was estimated that 30 per cent. of the farms in Alberta could be electrified in ten years, involving the electrification of 30,000 farms at the rate of 3,000 a year.

Utilities operating prior to 1944

Of the various private companies and corporations producing electrical energy prior to 1944—the date when the Alberta Power Commission came into being—the one most intimately concerned with hydro-electric development was Calgary Power Limited, formed as the Calgary Power Co. Ltd. in 1909. This concern procured a contract to supply the Calgary and Exshaw cement mills, and brought its first hydro-electric plant at Horseshoe Falls on the Bow River some fifty miles west of Calgary into operation in May 1911. In the following year the company completed a storage reservoir at Lake Minnewanka some thirty miles upstream and, early in 1913, commenced construction on the Kananaskis Falls site some two miles above the Horseshoe Falls plant.

Upon the completion of the Bow River plants the company made rapid growth. The system load which in the year 1922 was about 4,000,000 kWh increased steadily until in the year 1927 it was about 78,000,000 kWh and the load increased in 1928 to over 100,000,000 kWh. This load not only overtaxed the water-power plants but necessitated drawing heavily on steam power furnished by the Calgary Municipal Steam Plant, thus making it imperative for the company to extend its generating facilities to provide for some 175,000,000 kWh, which was anticipated for the year 1930.

Upon the consummation of satisfactory arrangements between the Province of Alberta and the City of Calgary, the company was authorised under provisions of the Dominion Water Power Regulations, to proceed with the construction of the Ghost-Radnor development consisting of a dam, reservoir and power station at the Radnor site some four miles below the Ghost site. The Ghost site was developed by the year 1929, but the Radnor site has not yet been developed.

By the year 1940 a further plant on the Bow River was required for the purpose of supplying power to an explosive plant to be constructed at Galgary. The company therefore was granted the right to enlarge the Lake Minnewanka reservoir and to construct the Cascade power station. Rights were also granted to the company to enlarge the reservoir at the Upper Kananaskis Lake which had been constructed in the year 1932. Along with this development a number of transmission lines were constructed for the purpose of tying the new plants in with the existing system.

A few small hydro-electric plants in the north west of the Province were operated by Dominion Electric Power Limited, and thermal stations were operated by Canadian Utilities Limited and the Cities of Edmonton, Lethbridge and Medicine Hat.

Alberta Power Commission

As already stated, the Alberta Power Commission was constituted by Act of Parliament in 1944, and

some idea of the progress made between that date and the end of 1951 may be gathered from Table III. On the distribution side, some 13,000 farms were connected over this period—a figure corresponding fairly closely to the estimate in the Alberta Research Council's report.

TABLE III. GENERATING CAPACITY AND PRODUCTION IN 1944 AND 1951.

	December 31, 1944	December 31, 1951
Power generating capacity (water power) kW	67,886	163,975
Power generating capacity (other sources) kW	97,364	140,789
Total power generating capacity kW	165,250	304,764
Annual production (water power) kWh	322,015,000	501,597,877
Annual production (other sources) kWh	233,019,000	578,592,591
Total annual production kWh ...	555,034,000	1,080,190,468

Bow River Developments

The most important hydro-electric developments have been on the Kananaskis and the Spray Rivers—both tributaries of the Bow River (see Fig. 2).

The Barrier power and storage development on the Kananaskis was authorised in 1949. The works consist of an earth-fill dam to raise the water level to a maximum elevation of 4,515 ft. mean sea level datum; a concrete sluiceway and intake structure in the earth-fill, a steel penstock to conduct the water to a power station located at the toe of the dam and a tailrace excavated in the bed of the Kananaskis River. The following are the essential features of the development:

Height of dam, 140 ft.; effective head, 151 ft.; rating, 13,000 kW; crest length, 2,318 ft.; gross capacity of reservoir, 35,962 acre ft.; net capacity of reservoir, 20,000 acre ft.

The construction cost as fixed by the company and approved by the Alberta Provincial Auditor is as follows:

	$
Supervision	23,062·62
Turbines, engines and auxiliary equipment	93,403·27
Generators, exciters and auxiliary equipment	145,060·05
Switching, metering and control equipment	44,934·99
Head ponds, reservoirs, dams	1,276,350·97
Headworks, water conduits, tailrace ..	297,821·91
Structures and land improvement ..	145,801·96
Miscellaneous equipment	16,736·02
Undisturbed construction expense ..	32,593·37
Engineering surveying	128,077·60
Interest during construction	98,032·63
Substation	58,079·83
	2,359,955·22
Transmission line	46,538·11
	$2,406,493·33

The Spray River is one of the main tributaries of the Bow River. It rises in the area south and beyond the Three Sisters range and is fed by the snows and glaciers along the Continental Divide between Mt. Assiniboine and the Palliser Pass. It flows northward to meet the waters from Upper and Lower Spray Lakes which are immediately south of Three Sisters Mountains, thence northwesterly through the Spray canyon and Spray valley until it finally joins the Bow River at Banff.

The main dam located on the Spray River, by raising the water 165 ft., creates a reservoir in the Spray Lakes valley which covers 4,800 acres of land. The reservoir has a capacity of 190,000 acre ft. which will not only be used in the Spray plants, but will be used to supplement winter flows at existing and future plants on the Bow River below Canmore. This dam backs up the Spray River over Spray Lakes. In order to contain the water a dam has been constructed in the Goat valley. This dam is 1,980 ft. long and 48 ft. high. Directly below the dam is located the Three Sisters power station which controls the flow of water from the Spray reservoir.

The water from the Three Sisters plant is carried by a system of level canals and dykes down Goat Valley and through Whiteman's Pass to the intake of the pressure tunnel high above Chinaman's Peak. Above Canmore this tunnel is 2,200 ft. long and drops water 905 ft. to the Spray power plant located at the foot of Chinaman's Peak. This tunnel was lined with cement at the upper end, the lower 500 ft. being lined with steel.

The main plant, the Spray, is located at the lower end of the tunnel under a head of 905 ft. The water from Spray plant is carried by a canal to a point close to the Bow River west of Canmore where it again drops down 325 ft. through a penstock to the Rundle plant on the Bow River.

The three power plants of the development have a combined output capacity of 88,600 h.p. The Three Sisters plant operates under a maximum head of 60 ft. and consists of a 3,600 h.p. propeller-type turbine with a 4,000 kVA generator.

The main equipment of the Spray plant consists of a 62,000 h.p. Francis-type turbine operating at 450 r.p.m. under a head of 905 ft. This is directly connected to a vertical generator of 47,500 kW capacity.

Rundle plant operates under a head of 325 ft., its 23,000 h.p. Francis-type turbine turning a 20,000 kVA generator at 300 r.p.m.

The construction cost as at September 30, 1951, was as follows:

	$
Storage development	4,453,889·79
Three Sisters Power Station	853,608·50
Spray Power Development	5,554,913·53
Rundle Power Development	2,028,734·08
Engineering and contingencies	95,151·60
Total	$12,986,297·50

In order to utilise all the flow created by the Spray development it was necessary to enlarge the Kananaskis Falls power station by 9,000 kW.

The station has been furnished with the necessary equipment to operate the Spray, Three Sisters, Rundle and Barrier power stations automatically.

The Bow River Problem

Water power undertakings on the Bow River, because of the low winter flow, are faced with the necessity of storing summer water for use in the winter.

whereas irrigation requires water during the summer months. The possibility of a conflict of interests between the two types of development therefore exists, and the problem arises to determine to what extent each should be allowed to develop and in what order of priority. As a result of comprehensive water studies it was determined that the effect of operating the Bow River for power development, including the Spray development, did not aggravate the irrigation difficulties but rather, by increasing the flow of the stream in April, September and October, increased the natural flow of the stream due to the release of water from the power reservoirs during these months. However, it was recognised that irrigation requirements had priority over requirements for power purposes, and that, for the development planned, the water supply study indicated that in low water years such as 1940 and 1941 the regulated flow of the Bow River was considerably below the peak requirement indicated. For this reason provision was made in the licence issued for the Spray development to the effect that during any period or periods of not more than ten days in the aggregate in the months of June and July of any year when the rate of flow of the Bow River, immediately below the Ghost plant, is less than 4,600 cusecs, there shall be released from the Ghost reservoir sufficient water to bring the flow immediately below the Ghost plant to 4,600 cusecs, but the total amount of water so released from storage during any year shall never exceed 20,000 acre ft.

A second problem is that of ice jams. Although ice jams along the Bow River at Calgary are known to have occurred long before the Ghost dam was ever constructed, and it would be difficult to prove that the operation of the river for power is the sole cause of any particular jam, most people are convinced that the following two causes are largely responsible for the annual ice jams that now occur at Calgary:—

(1) The average increase in winter flow of the Bow River due to the release of stored water for power development.

(2) The fluctuation of the winter flow at the Ghost plant in unison with the demand for electrical energy from the plant.

To what degree each of these causes is responsible is unknown, but together they contribute to the frequent winter floods which now take place along the river. The company has therefore been placed under obligation to operate the Ghost plant at a reasonably steady load until the Bearspaw or equivalent site has been developed.

Investigation of Future Water Power Sites

A major activity of the Alberta Power Commission has been the investigation of potential water-power sites. The more important sites are summarised below, and may be conveniently followed in conjunction with the map, Fig. 1.

Fig. 2. Map of the Bow River and its tributaries showing existing stations and sites for projected developments. The most recently completed scheme is that on the Spray River

Bow River

Bearspaw Site. Located about 10 miles above the city of Calgary. The controlling feature is the Canadian Pacific Railway line which skirts the north boundary about 50 ft. above the river. By extending the reservoir downstream for about two miles by means of a canal, it would be possible to gain approximately 25 ft., making a total power head of approximately 75 ft.

The estimated cost of this site at 50 ft. head is approximately $3,500,000. With the Bow River as at present regulated, the power available during the six winter months would be approximately 45,500,000 kWh. Although the unit cost for power generated at this site would be considerably greater than an equal amount of power generated by the Spray development, the combination of the two developments would be the most economical and desirable development in the Province. The reservoir, although not yet surveyed in detail, would probably have a storage capacity of 20,000 acre ft.

Glenbow Site. This site is directly above the Bearspaw site and is similar to it, except that the dam could be higher and more storage created without interfering with the railway. No estimate has yet been made of the available head and storage capacity.

Russell Site. This site is just above the Ghost Site and would discharge into the Ghost reservoir. The storage capacity would be about the same as the Ghost plant, although the available head is larger.

This site was considered in competition with the Ghost Site prior to the development of the latter. Foundation conditions are considered to be suitable for a fairly high dam at this location. This is considered a favourable site for a peak load plant.

Lac Des Arcs Site. By construction of a dam across the Bow River at Exshaw, it would be possible to create a considerable amount of storage capacity in the wide section of the Bow River valley between Exshaw and Canmore. To create such a reservoir it would be necessary to relocate a considerable length of the Canadian Pacific Railway through the area. A further possibility would be to raise the present Kananaskis Falls dam to a point where the area flooded would take in the reservoir proposed by a dam at Exshaw.

North Saskatchewan River

Carvel Site. This is a possible power site about 35 miles south-west of Edmonton. It is estimated that by the construction of a dam about 120 ft. in height and 1,800 ft. long at the crest, storage capacity of 400,000 acre ft. could be created. With the storage and head thus created, it is estimated that the potential firm power available would be about 20,000 h.p. The foundation is a sedimentary rock or clay shale. The effective head would be approximately 100 ft.

Rocky Rapid Site. This site is about 70 miles south-west of Edmonton. By the construction of a dam 150 ft. in height with a crest length of 1,600 ft., it would be possible to create storage capacity of 300,000 acre ft. Foundation conditions here indicate sandstone, which is considered suitable for such a dam. It has been estimated that the potential firm power available would be some 20,000 h.p. The effective head would be approximately 130 ft.

Gap Site. Located about 100 miles west of Red Deer. The area of the drainage basin above the site is about 1,800 square miles and the average run-off is about 1,800,000 acre ft. The section is such that a very high dam could be built. A dam 170 ft. in height would impound 300,000 acre ft. and a dam 320 ft. in height would completely regulate the stream. The firm power available at the site would be from 10,000 to 50,000 h.p., depending upon the height of the dam constructed.

Tershishner Site. Located about 35 miles south-west of Nordegg. A dam with crest length of 700 ft. at this location with a height of 200 ft. could be constructed on what appears to be solid rock. Present data indicate that this site is the most attractive yet discovered on the North Saskatchewan River. The estimated capacity is approximately 200,000 acre ft. and the effective head about 180 ft.

Whirlpool Site. This site is in the same general area as the Tershishner Site. A dam section is located in a canyon 150 ft. in depth, the crest length at that elevation being about 1,300 ft. It is estimated that the storage capacity which could be created for power development would be about 250,000 acre ft. This would provide firm power of 8,000 h.p. The effective head would be about 120 ft.

Nordegg Site. Located about 90 miles south-west of Edmonton just below the junction of the Nordegg and Brazeau Rivers. The crest length at 100 ft. is about 750 ft. The drainage basin above the site is approximately 2,500 sq. miles and the storage capacity about 44,000 acre ft. The effective head would be about 80 ft.

Cardinal River Site. Located just below the junction of the Cardinal and Brazeau Rivers. The section is a narrow canyon where a head of some 300 ft. could be created. The estimated firm horsepower would be about 800 h.p. The estimated capacity is about 75,000 acre ft. and effective head about 280 ft.

Clearwater Gap Site. Located on the Clearwater River. It is estimated that a dam about 150 ft. in height with a crest length of 1,600 ft. would impound some 200,000 acre ft. of water. Foundation conditions appear to be satisfactory for a dam of this height. If developed for water power, the storage capacity would be less than 200,000 acre ft.

Other North Saskatchewan River Power Sites. There are five possible sites between the junction of the Brazeau River to the town of Rocky Mountain House. Each would require the construction of concrete structures about 150 ft. in height with crest length of from 1,200 to 1,400 ft. The average storage capacity available for power development would be about 200,000 acre ft. The firm power which would be developed at each individual site would be about 15,000 h.p.

A number of other sites have been investigated on the Brazeau River, but their development is limited.

Athabaska River

Image Rock Site. Located about 160 miles north-west of Edmonton. Foundation conditions of sandstone and shale are considered satisfactory. In addition to a dam across the river proper, a large earth fill would be required on the north side. It has been estimated that about 18,000 h.p. of firm power would be made available. The drainage area above the dam site is about 4,600 sq. miles. Estimated capacity is about 250,000 acre ft. and effective head about 130 ft.

Gooseneck Site. A dam 200 ft. in height with crest

length of 1,500 ft. could be constructed at this site. The drainage area above the site is about 4,000 sq. miles. Estimated capacity is about 250,000 acre ft. and effective head of about 170 ft.

Wild Hay River Site. This site differs from the others in that it is a high head development similar to the Spray Lake development. Storage capacity of about 270,000 acre ft. could be created by backing the river into a long depression occupied by a series of lakes. Thus regulated, the flow available for the development of power would be about 500 cusecs. A head of 600 ft. could be created by tunnelling through the mountains between the Wild Hay reservoir and the Athabaska River, dropping the water through penstock and turbines into the latter stream. It is estimated that about 30,000 firm h.p. could be developed in this manner. By diverting the Snake Indian River into the top of the Wild Hay River the power capacity could probably be doubled.

The main dam on the Wild Hay River would be 150 ft. in height with crest length of about 1,800 ft.

Rocky River Site. Below the junction of the Rocky River and Medicine Tent River, the valley flattens out to form a possible reservoir; then runs into a canyon and drops 340 ft. in three miles. Possibly a reservoir could be constructed just above the falls and a pipe and penstock built to a power house below. A small lake at the top of the Rocky River could provide some storage.

Other Sites. Maligne, Brule and Jasper Lakes, and Grand Rapids.

It will be seen from the foregoing that although existing hydro-electric plants already make an important contribution to Alberta's economy, the potentialities awaiting development probably greatly exceed those now harnessed.

We are indebted to the Alberta Power Commission for the information on which this article has been based and also for the use of the accompanying maps.

Canadian Water Resources

Volume 103 of the Water Resources Papers, Surface Water Supply of Canada, has been published and is now available for distribution. This report contains run-off data for the climatic years 1947-48 and 1948-49 for the St. Lawrence and Southern Hudson Bay Drainage which covers the greater part of the Provinces of Ontario and Quebec. The data presented are the results for the period October 1, 1947, to September 30, 1949, of the hydrometric investigations which were carried out in the two provinces in large part by the Water Resources Division, although operations were facilitated by active co-operation received from the Hydro-Electric Power Commission of Ontario, the Quebec Streams Commission, the Quebec Hydro-Electric Commission, and a number of private agencies.

The report, which is bilingual in that the English and French versions are combined in the one volume, includes a short description of the organisation and scope of operations, an explanation of the method of tabulation, and 407 pages of stream-flow and water-level data for a number of rivers, streams and lakes in Ontario and Quebec. The appendix contains a reference list of hydrometric records for this drainage division, a list of available Water Resources Papers, and an index to the current issue.

This report may be obtained from the Chief, Water Resources Division, Department of Resources and Development, Ottawa 4, Ontario, at a price of $3.00 per copy, remittance to be in favour of the Receiver General of Canada.

New Angle on Pipe Corrosion

A communication received from the Department of Scientific and Industrial Research refers to an examination which has been made of iron implements, 2,000 years old, which may lead to new methods of protecting underground pipes from corrosion. Although the articles were buried in one of the most aggressive soils possible, they were found to be perfectly preserved. Tannates in the soil appeared to have completely prevented action by sulphate-reducing bacteria which are responsible for most cases of rapid corrosion in waterlogged clay soils.

The iron articles, ranging from hob nails to knives, were found during excavations by the Inspectorate of Ancient Monuments, Ministry of Works, on a site at Hungate, York. Normally, on a waterlogged site of this kind, they would corrode in a very short time. Because of their excellent state of preservation, samples of the soil in which they had been buried were examined by the Chemical Research Laboratory, D.S.I.R. Sulphate-reducing bacteria were found to be present but not active, though the soil would ordinarily have been highly aggressive towards iron. Scrapings from a Roman knife were examined chemically and it was found that there were traces of tannate in the little surface corrosion that existed.

The soil on the site was peaty and contained many leather cuttings. Several mediaeval shoes were also found and a number of knives which may have been used in the working of leather. It is believed that in the Middle Ages a Cordwainers' Hall stood nearby and that the area was the centre of a leather industry. This was the obvious source of the tannin in the ground.

Cultures were made of sulphate-reducing bacteria and inoculated with soil from the site. Their activity ceased if more than 5 per cent. was added. This result suggested that extracts from the leather were at least partly responsible. Other experiments using solutions made from the leather itself confirmed this.

Later work has shown that tannic acid in greater concentration than 0·01 per cent. stops the action of sulphate-reducing bacteria and it is hoped that the discovery may result in a method of protecting water and other pipes laid underground from corrosion.

Rock Drills and Tunnelling Equipment.—The Atlas-Diesel Company of Stockholm have issued three new publications relating to their rock drills and tunnelling equipment. The first of these, No. E841c, describes and illustrates various types of rock drills, "Coromant" drill steels, pneumatic pushers, bit grinders, loaders, air hoists; the second, No. E848, points out the advantages secured by using the "Swedish Tunnelling Method"; and the third is a somewhat whimsically produced instruction book which serves the serious purpose—to show how rock drills should be used to best effect—in anything but a serious way.

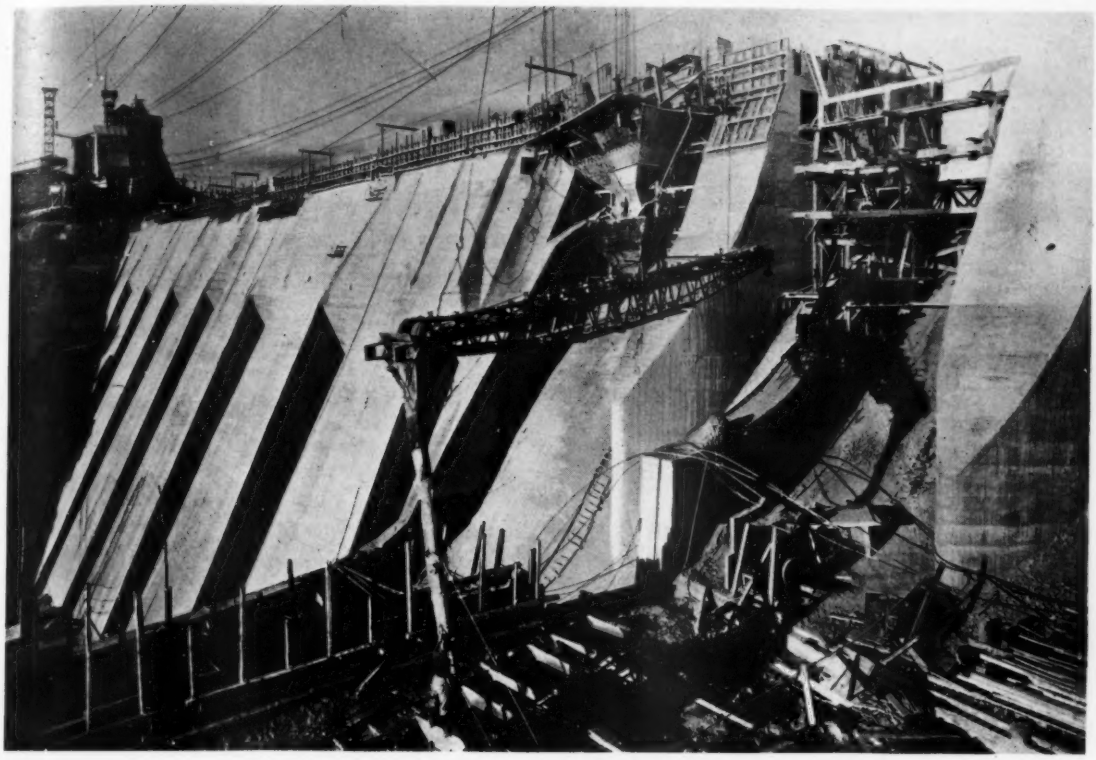


Fig. 16. Dam under construction with spillways in foreground

The Bau Muggeris Dam

In this second article the author, who designed the dam, describes the methods followed in its construction. In a final article the advantages of the cellular type of dam in comparison with the solid gravity type will be discussed.

By DR. ING. CLAUDIO MARCELLO

NOTHING exceptional has to be recorded about the excavation work for foundations, except for the following features:—

(a) The presence at the dam site, when the work was started, of about 10,000 cu. m. of masonry erected in accordance with the original design.

(b) The nature of the bedrock at the right abutment in connection with the porphyritic intrusion crossing the dam site to about 30 m. above the river bed.

As regards the existing masonry, some of it was demolished to accommodate the excavations for the buttress foundations which were deepened until a rockhead was reached showing enough soundness to support a structure of this magnitude. The masonry remaining within the dam cavities was left standing, leaving however, a wide continuous gap between itself and the concrete wall. Shafts were bored through the masonry to reach the rock and a number of drain holes were drilled through the rock itself along the perimeter of the cavities.

The buttress foundation crossing the porphyry intrusion was strengthened with a reinforced concrete slab, as previously pointed out. Pressure-jet washing and cement grouting to improve the porphyry rock took place mostly before pouring the foundation slab, the grouting being completed afterwards through the slab itself. This treatment, carried out in the porphyry through 30 to 40 m. of depth, changed its crumbling nature into sound concrete as was proved by repeated sampling. Drainage holes with different slopes were driven through the porphyry to collect the subsurface waters circulating upstream of it and held back by a clay curtain along its contact surface with the schist. Final excavation of this site was carried out

Fig. 17. Dam from upstream; note opening left to discharge water during early stages of construction

immediately before pouring the concrete.

Grouting for the cut-off wall had been partly carried out during the first period of the work (1941-43) in accordance with the original masonry design. The new layout of the dam required additional grouting between the foot of the upstream face of the new structure and the old cut-off partly constructed at the heel of the masonry dam. Test holes were bored to ascertain the effectiveness of the former cut-off wall. Grout holes bored during this stage amount to a total length of 1,600 m., the cement grouting amounting to 220 tons.

The diversion of the river during the construction period was greatly simplified by the hydrologic character of the stream, which, during six months of the year, allowed work to be carried on throughout the whole width of the bed, the discharge at Bau Muggeris during summer usually keeping below 1 cu. m. per sec. Foundation excavation along the river bed could therefore go on during low-water period

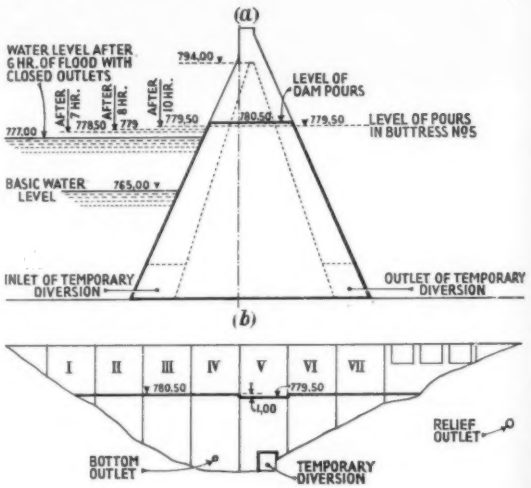


Fig. 18. (a) Range of water levels in reservoir with initial storage at El. 765 with flood of 1,200 cu. m. per sec. (outlets operating after 6 hours). (b) Scheme of concrete placings

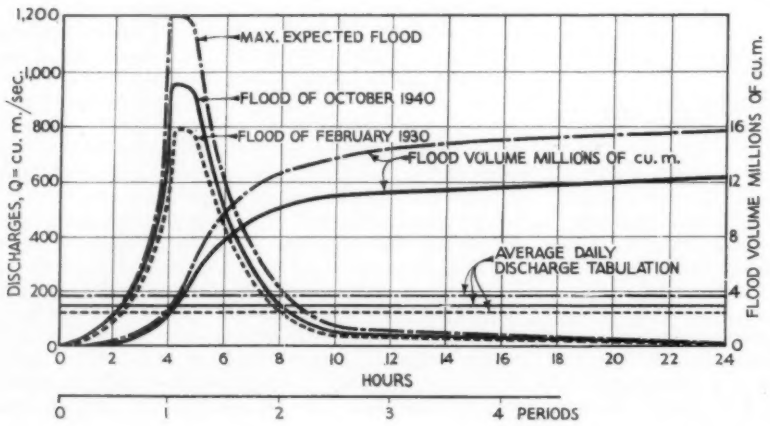


Fig. 19. Floodwater peak foreseen and maximum recorded values

with the provision of only a minor diversion channel. A large opening (5 × 6·50 m.) was left in the lower portion of buttress No. 5 in order to avoid the works being inundated with water during the wet period, when sudden and considerable floods are often experienced. Through this opening the river streamed off during the excavation work, the pouring of buttress No. 4 and during the construction of the bottom outlet, through which the low-water discharge was to flow, thus allowing buttress No. 5 to be completed.

To avoid the dam elements under construction being topped by flood-water, care was taken to ensure a free height betwen the storage level and the elevation reached by the lowest buttress. Such free height was determined according to the principles described below.

On the basis of the characteristics of major floods observed at Bau Muggeris the shape of a flood wave

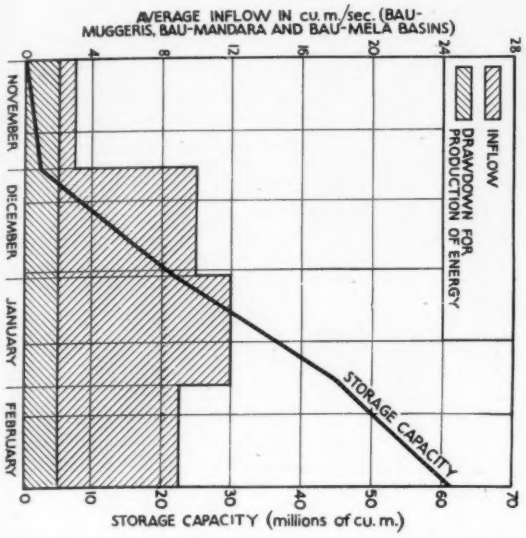


Fig. 20. Available discharges in winter months—average 1926 to 1935

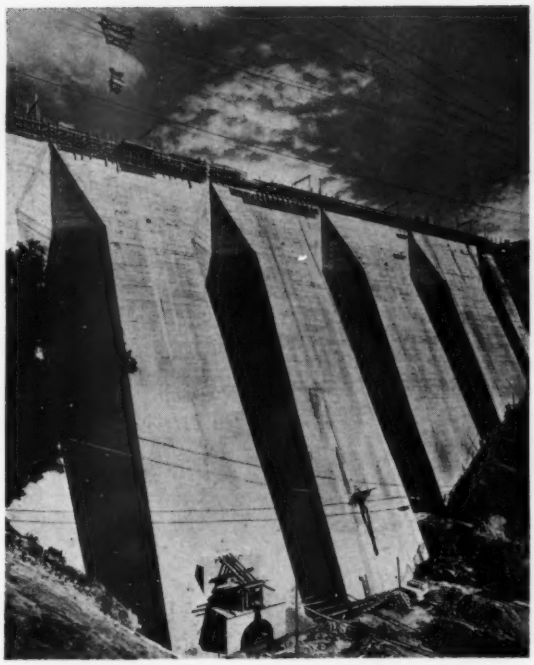


Fig. 22. The dam as seen from downstream

30 per cent. above the recorded peak was determined (Fig. 19). A computation was then made of the volume to be left empty in the reservoir, below the elevation reached by the lowest dam element, to accommodate the lamination of the flood peak when taking into consideration the deduction of the flow discharged through the main and subsidiary bottom outlets which is assumed to start operating at the sixth hour from the beginning of the flood (Fig. 18). It was thus possible to obtain the curves shown in Fig. 21, which determine the allowed maximum storage levels with reference to the elevations reached by the dam. By this provision it was possible to start water storage

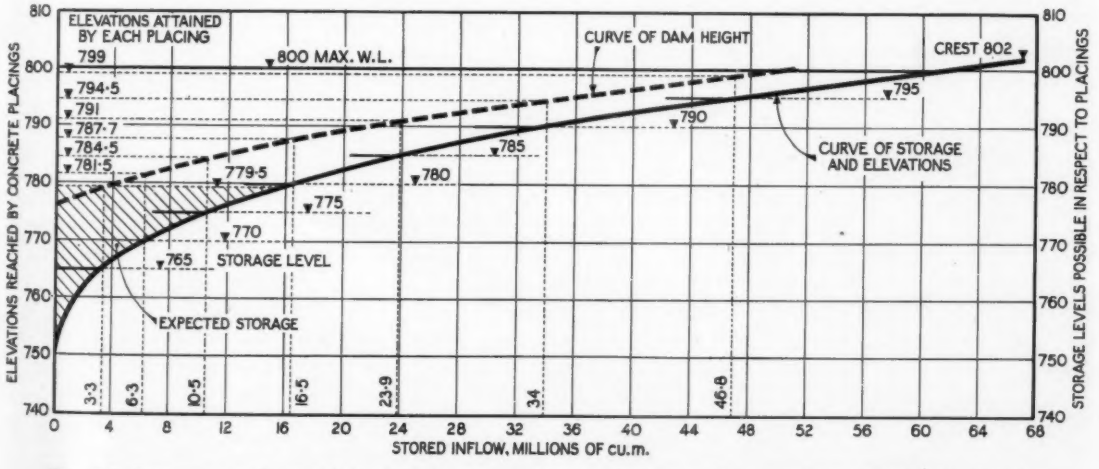


Fig. 21. Storages made possible during construction in relation to the elevations attained by the dam concrete placings, assuming a flood of 1,200 cu. m. per sec. The floodwater is partly stored in the reservoir and partly discharged through the bottom outlets, outlets operating after six hours

during the winter of 1948, thus allowing the power plant to be put into service in the summer of 1949.

The Concrete

Cement: Normal Portland cement was employed, mainly supplied by the Cagliari factory of the Italcementi Company. Check determinations of the tensile and compressive strengths of the standard mortar, of setting time, and other tests were carried out in the field laboratory during the whole construction. Similar tests on the same mortar were performed in the Laboratory for Testing Materials of the University of Milano. The average data furnished by the latter for the compressive strength of standard mortar were as follows:—

at 7 days: 454·4 kg. per sq. cm.
at 28 days: 563·1 kg. per sq. cm.

Water: The ascertained pH of the Flumendosa water (used for the mixes) in the vicinity of the dam, tested monthly during low-water period, varied between 7 and 8.

Aggregates: The aggregates used for the construction were obtained by crushing a granite which outcropped about 1 km. upstream of the site of the dam.* This rock is a fine-textured granite

*The possibility of utilising limestone from an outcrop about 4 km. from the site was discarded in view of the time schedule.

Fig. 23. Dam being concretea, showing cellular construction

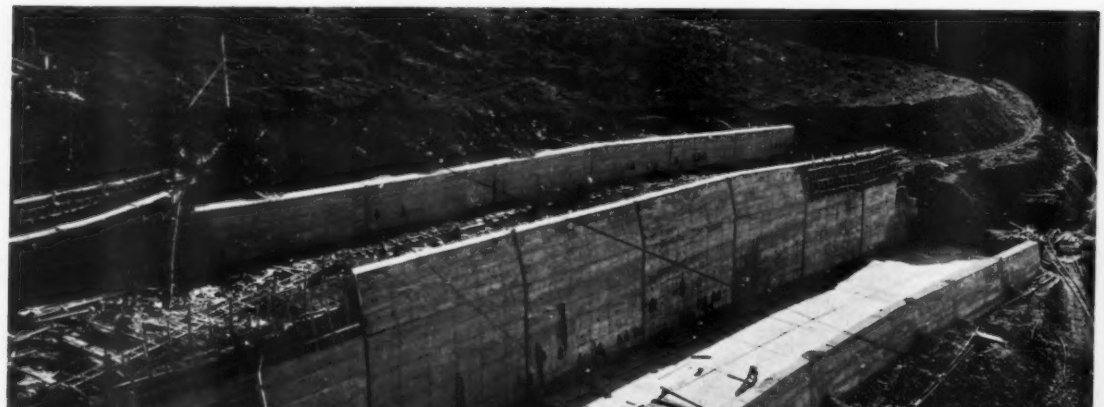


Fig. 24. Spillway channels under construction

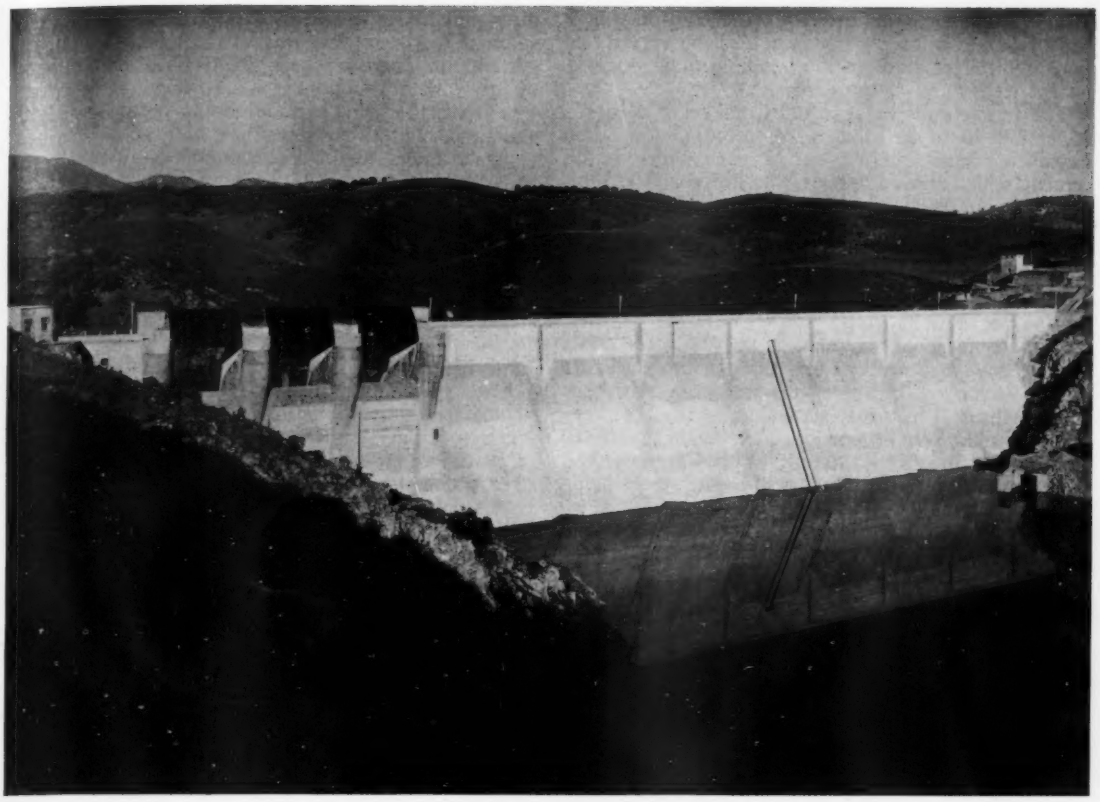


Fig. 25. Completed dam as seen from left bank

with a high silica content, and involved a considerable wear of steel in the drilling and crushing processes.

Aggregate grading was assumed in accordance with the Bolomey curve with constant A = 15 and maximum size of 70 mm. in a first period and of 85 mm. subsequently.

The final grading adopted for the concrete (four aggregate classes besides the very fine) corresponds to a slightly higher curve than $p = 15 + 85\sqrt{d/85}$ which, on the basis of a number of tests, was found to be the most suitable to ensure the required density and strength of concrete. For the mix with $D_{max} = 85$ mm., the composition by weight was as follows:—

	per cent.
— very fine, cement and fine (0 to 0·5 mm.)	21·94
— sand (0·5 to 6 mm.)	17·30
— fine gravel (6 to 15 mm.)	14·40
— gravel (15 to 30 mm.)	13·80
— coarse gravel (30 to 85 mm.)	32·50
	100·00

The weekly checking of the actual grading of the aggregates showed minor discrepancies from the theoretical grading.

Cement was kept between 240 and 210 kg. per cu. m. as required in the different zones of the dam: a small amount of cement grout was used in the vicinity of the upstream face.

Test cubes of concrete, of 20 cm. side, were taken once a week direct from the concrete mixer and tested partly at the field laboratory and partly in the laboratory of the Engineering High School of Naples. This laboratory issued the following average values obtained from 292 cubes:—

— specific weight . . . 2413 kg. per cu. m.
— compressive strength { at 28 days . 324 kg. per cu. m. / at 90 days . 387 kg. per cu. m.

Concrete Plant

The quarry was exploited in steps averaging 20 m. in height and about 200 m. wide. The loose material was cleared and fed to a primary crushing and screening plant located in the immediate vicinity of the quarry and somewhat below it, by means of two 1 cu. m. excavators and two 10 cu. m. box lorries (Euclyd type). The rubble, not more than 20 cm. in size, was conveyed to a 500 cu. m. stock pile feeding four secondary crushers.

The crushed stone produced here was elevated 15 m. by belt conveyors to a set of four rotary screens which were erected above a set of silos, each divided into six chambers, two for material to be fed to the tertiary crushing machines (16 granulators and two ball mills for production of the very fine) and four stockpiles, having a capacity of 500 cu. m. each, for storing the four classes of aggregate.

The output from the tertiary crushing plant was discharged by a belt conveyor on to the same belts feeding the rotary screens, thus forming an arrangement having wide possibilities of quickly varying the grading to that desired to meet immediate require-

ments. A cableway about 1 km. in length, having a capacity of 35 cu.m. per hour, ensured the transportation of the aggregates to the batching plant, located on the right bank at the dam site.

The four classes of aggregates (0·5 to 6; 6 to 15; 15 to 30; 30 to 85 mm.) were stored in four silos having a capacity of 500 cu. m. each, whereas the cement, which arrived in bags, was stored in a 120-ton main bin or in a 100-ton storehouse. A system of screw conveyor and bucket elevator fed the material from this storage into a sheet-steel bin, of 7 tons capacity, installed above the mixers. A further sheet-steel bin, coupled with the cement bin, was provided for the very fine material.

Proportioning of aggregates was effected on a volume basis by means of travelling calibrated trucks which discharged the aggregates on to conveyor belts feeding three 1 cu. m. mixers. Cement and the very fine aggregate were proportioned by weight, by means of weighing machines. Mixing water was measured by means of steel plate tanks, the water level being adjustable to suit the general conditions—air dampness, aggregate water content, quantity of cement and very fine aggregate—thus attempting to satisfy, through repeated trials, the two opposite requirements of workability (hindered by the extreme coarseness of the aggregates) and of the smallest water content of the mix. Consequently, the water-cement ratio varied—within very narrow limits, however—around the average value 0·6. The concrete was taken from the mixers by means of three conveyor belts and discharged into the feed hoppers of three cableway cranes (Blondins) for transport and placement.

The three Blondins, installed respectively upstream, downstream and on the centreline of the dam, were mounted on stationary towers; the first two were equipped with 1·5 cu. m. buckets and the third with a 2 cu. m. bucket. A fourth unit, mounted on movable tower, served for the transport of various materials. The buckets, through automatic opening, discharged concrete into wide hoppers which were movable both vertically and horizontally and suspended on ropes stretched across the gorge. The placing of the concrete was accomplished by the aid of a revolving frame attached to the hoppers and supporting a 20 m. long horizontal conveyor belt, through a short trunk, to prevent segregation of aggregates. Concrete was placed in 50 cm. lifts and carefully treated with Jackson-type electric vibrators (about 4,500 revolutions per minute).

Cleaning of the surfaces for the new lift was made by chipping and washing with high-pressure air and water jets; thereafter, a layer of cement mortar a few centimetres in thickness was laid down to receive the concrete. Wooden forms consisting of 2×1 m. panels, with a sheet iron lining for the upstream face only, were used and were supported and linked together by means of 4 mm. iron wire ties.

The concrete for the dam alone amounted to 132,000 cu. m., and represented 88 per cent. of the entire constructional cost; the cost of excavation was 9·3 per cent. and of the miscellaneous installations 2·7 per cent. Working man-hours required for construction of the dam totalled 1,850,000.

Construction of the dam and auxiliary works was contracted for in the summer of 1947; the field installations were ready by February 1948; pouring was started on March 20, 1948, and finished by the end of April, 1949, in spite of the work having been discontinued one month owing to a strike. During the summer the pours reached the rate of 17,000 cu. m. per month. There was practically no discontinuance of the work during winter; a slow-down in the work was recorded during the months of December, 1948, and January and February, 1949, and can be ascribed to some extent to the frequent rains, but chiefly to some difficulties with the labour force so that it was not possible to obtain more than eight working hours per day. Pouring was started at element No. 1 on the left bank, which offered the possibility of granting time to get the concrete plant into operation while working on a small-height section of the dam. Water storage was started by the middle of January, 1949.

Logistic and Sanitary Provisions

The construction of the Flumendosa project involved a number of difficulties, incidental to the location of the site being so far from the main centres of Sardinia and especially arising from the distances over which the machinery and part of the materials required for field equipment, as well as for the plant itself, had to be transported. All this equipment was supplied by north Italian firms and about 11,500 tons of cement were transported from Genova and Civitavecchia. A system of sea-transport had to be provided, by organising a small motor-ship fleet and improving the dock installation of the minor port of Arbatax. A problem of no less difficulty was the organisation of land transport by means of lorries, owing to the state of existing roads.

Another problem, of a sanitary character, showed signs of special seriousness when work was resumed in 1947; indeed the working area and especially the site of plant No. 2 was infested by malaria, which in the first phase of the construction (1941-43) had accounted for several victims and in certain periods had obliged the work to come practically to a standstill. The anti-malarial campaign was commenced in 1947, and from 1948 was conducted under the direction of U.S.A. doctors with adequate and modern means supplied by America. The results were very satisfactory, as no new case of malarial infection was recorded on the scene of operations, not even at the ancillary works located at lower elevation, during the whole period of the working.

The Bau Muggeris dam was designed by the author, who also, in co-operation with Dr. Ing. Carlo Semenza, supervised the actual construction. Field management for the completion of the three hydro-electric plants (1947-49) was carried out under the competent care of Dr. Ing. Giorgio Forlì with the assistance of Dr. Ing. Carmelo Scribano, and for the Bau Muggeris dam by Dr. Ing. C. Corrado and Geom. A. Birelli.

The contract for the dam was let to "Impresa Lodigiani," a contracting firm with headquarters in Milano, who functioned under the field direction of Dr. Ing. G. Zanchi.

The waterproofing of the foundations was carried out by Impresa Rodio of Milano, who had begun this work in 1941, at the commencement of construction of the solid gravity dam. The apparatus for controlling the outlets were supplied by the following firms:—Spillway: three automatic sluice gates, by S. A. Franco Tosi of Legnano. Main bottom outlet: "Officine Galileo" of Battaglia Terme (Padova). Subsidiary bottom outlet: by "Galileo" and "Franco Tosi."

(To be continued)

Water-Turbine Governors and the Stability of Hydro-Electric Plant

In this series of articles, the water-turbine governor is considered in relation to control of the electrical transmission network, as well as to regulation of the water supply system including the surge tank. The principles underlying the design and operation of water-turbine governors are reviewed and a typical oil-pressure governor is described in some detail, along with its pressure oil supply. A short general account of the double regulation system for water turbines is then given, and is rounded off by a discussion of the stability of water-turbine governors.

By N. G. DENNIS, M.A., D.I.C., A.M.I.Mech.E., A.M.I.E.E.

PART ONE

THE last few decades have seen the development of large electric power stations linked together and to consumers by means of extensive power networks. In the hydro-electric field both the size of individual water-turbine generating sets and the rate of construction of hydro-electric installations have increased greatly, and the water-turbine governor with its associated controls plays an important part in these developments.

Up to the end of the nineteenth century, the application of hydro-electric power was severely restricted by the necessity for direct mechanical drive of the load, and the governors controlling these water turbines were insensitive and sluggish by present-day standards.

One thing which has not altered is the basic principle upon which the governor of any prime mover operates. Fig. 1 is an elementary diagram of a governor for a turbine where the working fluid is water. The basic principle of regulation is, of course, that if the speed of the generating set is not at the desired value, the speed-sensitive device operates the valve which controls the flow of working fluid through the turbine so as to regulate the driving torque on the turbine and hence the speed. Thus, if the speed is too high, the valve closes and, in this way, speed governing is attained. However, the advent of large-scale electrical transmission of energy has demanded a much higher standard of operation of the governor, and also has required it to perform many other functions.

Large hydro-electric power plants and complex power distribution systems mean the precision control of large flows of electric energy. For big power stations where stability is critical, the designer is confronted with intricate control problems where the maximum rate of action without instability is very important. Within the requirements of overall economy, the guide vanes of large turbines have to be operated with the minimum time lag, and the control must be highly sensitive.

Two special difficulties are presented by the governing of water turbines as compared with other prime movers. The first is the high inertia of the working fluid, particularly in relation to the inertia of the rotating parts of the generating set. The second difficulty is the heavy regulating mechanism which has to be moved. This mechanism has to be rugged to provide the large controlling forces, and inevitably there is a certain amount of friction, especially because the working fluid is natural water which contains varying quantities of sand and silt.

When the guide vanes move, the inertia of the water causes changes in pressure at the turbine which act contrary to the effect of the guide-vane movement on the speed and load of the turbine; to counteract this effect and avoid hunting, special stabilising devices have to be incorporated into the governor. Fast movements of the heavy regulating mechanism necessitate a high degree of amplification in the control mechanism, and the operating servomotors often are very powerful.

The construction of water-turbine governors is very closely linked to the choice of the necessary moment of inertia of the rotating parts of the generating set. Present-day practice in the choice of GD^2 is largely based on semi-empirical figures of the overspeeds and the over-pressures which follow major load rejections. In the view of many authorities on the subject, these guarantees should be transferred to the more logical bases of margin of stability and closeness of speed control. The old practice is regarded by many as an obstacle in the path of technical progress towards cheaper and lighter generating sets. In this connection, Stein (1947) has pointed out that the weight per horsepower of high and medium-head turbines has already decreased from 150 to 3 kg. in the course of the last century, largely, of course, as a result of improved runner design and of development in materials.

With certain important types of plant, the basic hydro-mechanical difficulties of governing are increasing. In other words, the hydraulic inertia is tending to increase and the mechanical inertia of rotation is tending to decrease. Big low-head Kaplan turbines for run-of-river stations and tidal power plants are en-

countering hydraulic time constants up to 4 sec., compared to the more usual figures of 1—1·5 sec. A further difficulty of governing is the development of higher specific speeds for such plants, since this means a flatter torque-speed curve of the turbine, hence poorer self-regulation. Also some recent very high-head Pelton plants have large hydraulic time constants on account of high water velocities in the penstock.

In addition, effort is also being made to cheapen the main generators by reducing the weight. This entails a reduction in the "natural GD^2" of the generator. However, on the old basis, higher overspeeds are likely to become permissible because of a more accurate theoretical approach, better experimental data, and less fundamental mechanical and electrical concern over the value of the overspeed attained, providing that this is well within the runaway speed and stability is not endangered.

In connection with power-system control, Crary (1947) comments that the first stage of development is just finishing, and the objective of this stage was no more than to furnish a sufficient amount of reliable power to the consumer. It is considered that a second stage is just beginning, where greater consideration must be given to capital investment and operating cost in order to obtain greater overall economy.

Water-turbine governors are often applied to tie-line bias control of the connections between electrical networks. The governor then usually responds to net-interchange variations, and in this case it attempts to keep the total power exchange constant on all tie-lines radiating from the system. By such automatic control, interconnections are operated nearer stability limits, tedious manual control is eliminated, and mutual co-operation between adjacent networks is greatly improved. A special case of tie-line load control is that where the effect of very heavy fluctuating loads such as steel mills can be localised. These big load changes can be met locally by providing an adjacent power station with rapid-action governors. These severe power variations, then, do not affect the bulk of the network and do not upset the normal steady distribution of electricity; in this way the danger of losing synchronism with the rest of the network also is reduced. On any network, the rates of response of the various governors have to be matched adequately to give stability of the team response to load changes; otherwise, a small system when violently disturbed may drop out of step.

The tendencies in the design of water-turbine governors probably are twofold. For very large stations, the expanded requirements of the network tend to require a greater degree of complexity. On the other hand, small generating sets will be more and more regarded as inseparable members of a team where individual regulation guarantees may be greatly relaxed. For many such turbines the centrifugal device probably will be omitted from the governor. One advantage of such an arrangement is the alleviation of the high relative cost of the governors for small stations; and, also, the surge tank frequently can be reduced in size or avoided.

The above paragraphs have dealt briefly with the relationship between the water-turbine governor and the electric network. In recent years, the importance of the governor in the other direction of the overall control pattern has been more appreciated. Evangelisti (1950) and Stein (1951) have pointed out that the stability constants of the governor and the self-regulation of the turbine and its connected load have quite an appreciable effect on the stability of surge tanks. Although the mathematics appear accurate, the time constants involved are so widely different that a clear physical explanation of this phenomenon is eagerly awaited. The stabilising effect of the governor on the surge tank can be further improved by a transient feed-back from the surge-tank water level to the turbine governor. This has been investigated by Cuenod and Gardel (1950 and 1952) both for surge tanks and for free-level canals.

Surge-tank stability may be influenced by interconnection of hydro-electric plants which have surge tanks of very different time constants; such interconnections increase the stability of the individual surge tanks (Evangelisti 1950). However, it is recognised that interconnection of generating sets does not in itself produce any appreciable increase of governor stability; a hydro plant which is individually unstable can work satisfactorily when connected to the network, but only at the price of a decrease in the margin of stability in the whole network. In fact, water-turbine governors frequently incorporate a device which, by reducing the stabilising action of the governor, increases the rate of action when required for rapid frequency control on a large network.

It is seen that features which were previously considered to be independent control problems, such as the surge tank, the governor, and network control, are now being increasingly regarded as one comprehensive control scheme. Such an approach promises increased overall economy of construction, since severe problems encountered in one quarter frequently can be overcome by appropriate action in another quarter. Thus, for example, an awkward question of governor stability may be relieved greatly by suitable design of the automatic voltage regulator so as to improve the self-regulation characteristic of the generating set.

There is still a great deal of work to be done towards improving practical knowledge of this very intricate question. It is likely that greater recourse will be had to model experiments and simulators. Probably, such experiments will co-ordinate present-day processes for the investigation of individual problems such as surge-tank and free-level channel stability by hydraulic models, of governor behaviour by hydraulic models or servo-simulators, and of network analysers as used at present for the investigation, by simulation, of network behaviour.

Principles of Operation of Water-Turbine Governors

Fig. 2 is a diagram which elaborates Fig. 1. The only movement shown in Fig. 1 is movement 1 of

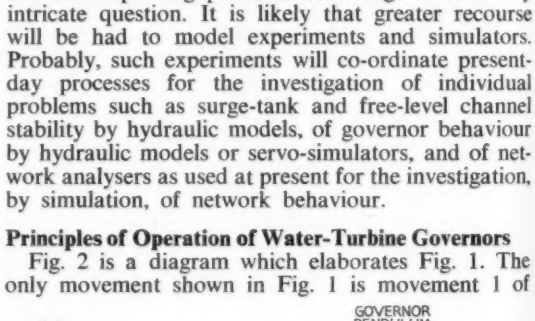


Fig. 1. Rudimentary governor

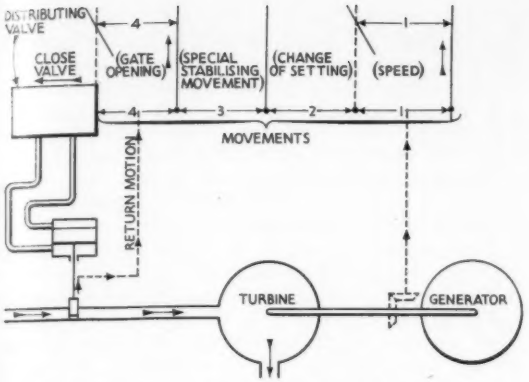


Fig. 2. Movement added at main distributing valve

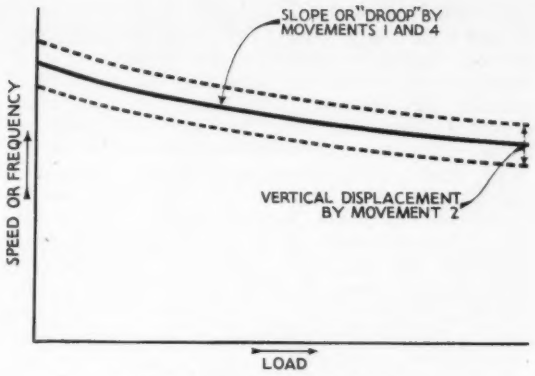


Fig. 3. Speed-load relationship

Fig. 2. The special difficulties of governing a water turbine mean that a special stabilising movement (No. 3) must be applied to the distributing valve. Without this movement, severe hunting would occur and the turbine would be uncontrollable. A return motion (movement 4) is transmitted from the movement of the main valve (guide vanes) and this also affects the position of the distributing valve. Another movement is provided (movement 2) which can be adjusted in order to change the steady setting of the governor. These four movements are added together and the algebraic sum determines the movement of the distributing valve piston and hence the movement of the main servomotor. Any deviation of the regulated quantities (speed or load) causes a change of movement 1 or of movement 4 which actuates the distributing valve and the main valve to correct the deviation. Steady combinations of movements 1 and 4 constitute the speed-load droop. Movement 2 is the familiar change - of - speed device which becomes primarily a change-of-load device when the unit is connected to a network; this changes the datum combination level of the speed-load relation as shown in Fig. 3. This diagram applies to the governor of any prime mover, except that the special stabilising movement (movement 3) usually is unnecessary. An example of a modern governor is given later in this series of articles, and it will then be useful to consider this in conjunction with Fig. 2.

A further elaboration of the governor diagram is shown in Fig. 4, which is a comprehensive block scheme covering the entire governor system for water turbines. This also shows a very small part of the generator and network control sequences. Fig. 2 is included in Fig. 4, since the movements in Fig. 2 are added by means of the arrows radiating from the

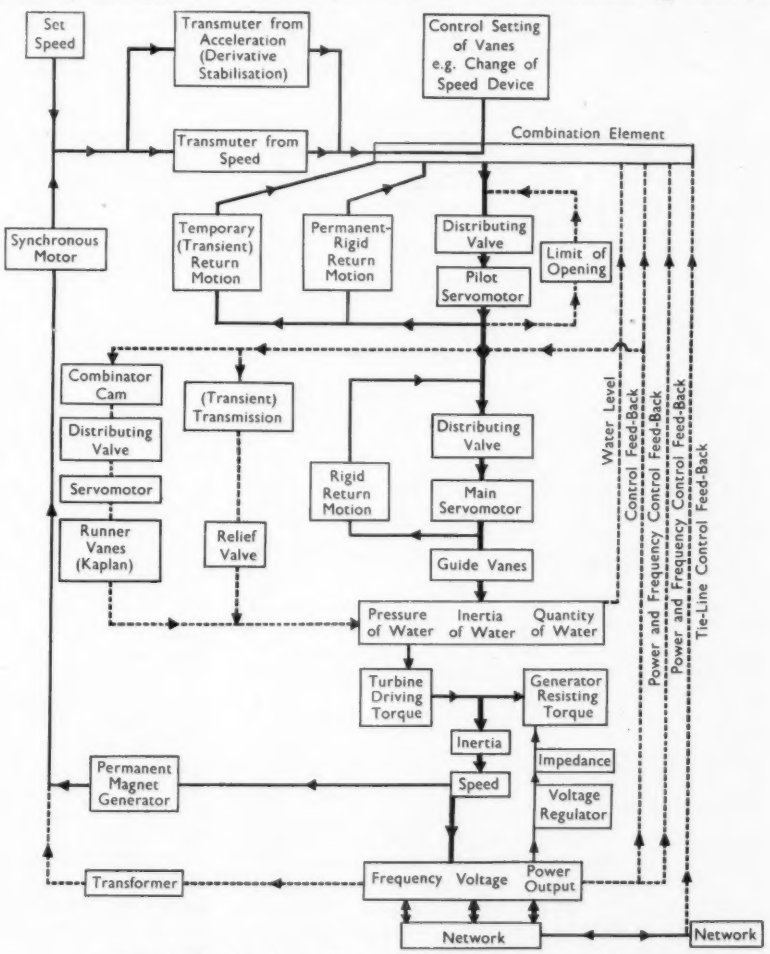


Fig. 4. Block scheme for control of a reaction turbine

combination element of Fig. 4. This figure is intended to give a general picture of the control loops associated with the turbine governor, and, to be concise, all these are shown on the same diagram, although in practice they will not all be present on the same governor at the same time. There are some advantages to be gained from showing the governor as such a block scheme rather than as a diagram or series of drawings, because the fundamental principles of operation are brought forward clearly without confusing the question with details of design. Since, in principle, the diagram applies to any governor, whether hydro-mechanical, electrical or electronic, the diagram enables constructional practice to be analysed later in these articles. Descriptions involving different permutations and combinations of designs of individual control elements are avoided. The diagram will be found to apply to any make of governor, although slight differences may exist, such as the exact point in the main sequence from which the relief-valve actuation and feed-backs are taken.

Governor technology is a sphere which has been, and is being, increasingly influenced by the electrical engineer. The co-operation between mechanical, electrical and civil engineers is becoming ever more desirable and necessary.

For appreciating the method of starting and stopping the turbine with the arrangement shown in Fig. 4, a similar diagram (Fig. 6, Frost and Brittlebank 1951) is very useful.

Operation usually requires that the guide vanes be capable of relatively rapid movement, and hydraulic servomotors are usually employed on account of their high power, low inertia, and simplicity. Hydraulic servomotors are also used for operating the runner blades of Kaplan turbines.

Hydraulic servomotors can be replaced by electric motors with reduction gearing, but this is usually restricted to comparatively small turbines where quick action is not required. These main servomotors are part of the high-power side of the governor control system.

The low-power side of the control system is that part of the governor ahead of the main servomotors in the control sequence, and it is here that the use of electrical devices is likely to become extensive. It is the author's personal belief that mechanical devices will become obsolete within the next few decades after suitable and reliable electrical devices have been developed. This is a general tendency of servo-mechanism practice.

Fig. 4 specifically refers to a reaction turbine, but with a few modifications can apply equally to an impulse turbine. The thick vertical centre-line of the diagram includes the fundamental elements of the governing sequence, as follows:—

(1) The combination element as shown pictorially in Fig. 2.

(2) The hydraulic amplifier—two units in series are shown in this case.

(3) The motion of the turbine guide vanes.

(4) Hydraulic conditions in the pipeline. Pressure, inertia and quantity of water have to be shown within the same rectangle, since in general they are mutually related in a very complicated fashion on account of the effects of water hammer and of surge tank or of canal behaviour.

(5) The difference between turbine driving torque and generator resisting torque acts on the inertia of the rotating parts to produce changes in speed. Speed is, of course, synonymous with frequency, if pole swinging in the generator is ignored. Variations in the speed and in load demand influence the voltage regulator and the generator resisting torque, which in turn affects the speed to form another small control loop.

The principal feed-back is, of course, that of the speed, and this can be considered to convert the open-sequence into a closed-sequence control system.

The speed feed-back is shown as a synchronous generator (or special transformer) and a synchronous motor, which latter drives the centrifugal element of the governor. The setting of the spring in the centrifugal element determines the required normal speed of the generating set. In the centrifugal element a mechanical displacement occurs which usually is proportional to the difference between actual speed and set speed. This displacement acts on the combination element to form the closed speed-control loop.

Unlike most other prime movers water turbines are found to require special stabilising elements in this loop in order to avoid hunting, and these can be provided by either of two methods, namely, transient feed-back stabilisation (temporary return motion), or derivative stabilisation (the addition of an element sensitive to angular acceleration). Whiteley (1947) gives a good general description of these principles, and it is not proposed to enter into a detailed discussion here. The physical principle of both methods is to advance the control signal in time, and hence obtain an anticipatory action which is stabilising.

A description is given later of the function of other feed-backs shown on Fig. 4. The conditions for the satisfactory operation of simultaneous feed-backs are of the utmost importance. The only feed-backs which can operate simultaneously are those which form part of the same major control loop; or feed-backs from interrelated variables, probably with very different time constants. Turbine gate opening and water-level control can act together, because the water level is a function of the turbine discharge and hence of the gate opening. Simultaneous operation of feed-backs allows the turbine gate opening to be influenced by speed, frequency, water level, etc., all at the same time; but the basic control equation fed into the governor should not have more than one degree of freedom. By this is meant that the control equation must have only two control variables in it; one of these will represent a power, and the other speed or frequency. Thus, in a simplified view, the second variable acts as a dependent variable which is fixed by the equation to be a function of the first independent variable; such a simplification is often given when a generating set is coupled to a large network and the frequency is then said to determine the turbine output. What actually takes place is that the impedance of the customer's load sets up a further equation between frequency and power. There are thus two simultaneous equations containing the two variables, frequency and power, and hence definite steady values of the two variables emerge from the control system. Therefore, the fundamental reason for the governor equation to have no more than one degree of freedom is that there is only one other equation between speed and power, and this is fixed by the load.

(Continued on page 76)

Power Development in Austria

In this article Dr. Erwin Königshofer touches on the chief points of a report* issued by the Austrian Government on the water-power resources of the country.

THE first Austrian Republic was created in 1918 after the dismemberment of the Austro-Hungarian Monarchy. During that period the commercial development of water power for the generation of electricity had been neglected, chiefly because the Monarchy's rich coal mines permitted an almost unrestricted use of fuel for the thermal generation of power. In 1914 the territory later forming the Austrian Republic had an installed capacity of only 166,000 kW, whereas the present capacity amounts to about 1,500,000 kW. In 1918 the coal mines fell to the Successor States and the Austrian Republic was compelled to develop its own hydro power to greater purpose. In spite of the lack of funds water-power development showed good progress, and by 1933 hydro-power plants with a capacity of 560,000 kW and a production of 1,850 million kWh had been put into operation. Of special importance are the power stations at Vermunt with a capacity of 90,000 kW and a production of 150 million kWh, developed by the Vorarlberger Illwerke Company, and the Achensee station in the Tyrol (capacity 86,000 kW), which, together with the later accomplished Dürrach diversion, produces about 200 million kWh in the normal year. In addition, various schemes for public supply and power plants for the electrification of the Austrian Federal Railroads were brought into operation. In 1930 steam traction could be substituted by electric traction on the section from the Swiss frontier to Salzburg. The erection of the transmission lines required by these plants formed the basis of the Austrian Federal Grid which was later created.

In the years preceding the German occupation and the second world war the development of the Austrian power industry did not make any progress worth mentioning.

In the period from 1938-1945 a great number of schemes primarily adjusted to German requirements were taken in hand but not accomplished, the only exceptions being the Stubach II station of the Austrian Federal Railroads, the Dionysen generating station and the Schwabeck station on the Drau River. The Lavamünd and Unterdrauburg stations on the same river, Obervermunt in Vorarlberg as well as Bösdornau and Plankenau were put into operation with only part of their capacity. Unterdrauburg fell to Yugoslavia and the Dionysen station was subsequently dismantled.

In 1947 the Austrian power economy was reorganised in so far as the Federal Law of 1947 (the second "Nationalisation Law") established a legal basis for combining all the Austrian interests concerned.

This law provided for the following companies:
(1) The Osterreichische Elektrizitätswirtschafts A.G. (Verbundgesellschaft) which became the owner of the high-tension grid and distributor of electric power to big consumers. It is organised as a company and administrates in the interests of the State with regard to the Special Companies and Provincial Companies;
(2) The Special Companies (Sondergesellschaften) are concerned with the establishment and the operation of large power stations;
(3) The Provincial Companies (Landesgesellschaften) supply the ultimate consumers in the Federal provinces;
(4) Municipal Power Companies operate the local distribution networks of five cities;
(5) Some industry-owned power plants are providing power supplies to third parties.

This organisation operated successfully from the start, and the installed capacity of the public supply plants, industrial plants, and the Austrian Federal Railroads plants increased from 1,600,000 kW in 1947 to 2,200,000 kW in 1951.

The Austrian Federal Grid operated by the Verbundgesellschaft, includes the 220 kV west-east main transmission line leading from Kaprun via Ernsthofen to Bisamberg (Vienna). This transmission line is to be extended to Burs to connect the two main lines Ernsthofen-St. Peter-Ludersheim-Remptendorf and Burs-Herbertingen-Brauweiler. These lines are the cpine of a future Inter-European network. At present the Verbundgesellschaft is erecting the Austrian section of a 220 kV line to connect the Austrian and the Italian grids with a view to creating the means of exchanging electric energy.

The Special Company Tauernkraftwerke A.G. is constructing Glockner-Kaprun power plant to which reference was made in the November 1952 issue of this journal.* The main stage has been finished and comprises the Kaprun generating station, 200,000 kW capacity, and the Wasserfallboden reservoir with a storage reserve of 86 million cu. m. The upper stage includes the Mooserboden reservoir, storage capacity 86 million cu. m., the Limberg generating station, 112,000 kW, and works for the diversion of the run-off of the Pasterze glacier. The total production of the two stages will amount in the normal year to 600 million kWh. Another 200 million kWh can be generated by pumping, the required energy for the pumps being 300 million kWh.

The Special Company Ennskraftwerke A.G. have erected four stations—Grossraming, Ternberg, Staning and Mühlrading—all operating from cascades on the Enns River. The power plant is also under construction at Rosenau.

The Special Company Österreichische Draukraftwerke A.G. operates the stations along the Drau River and has the Kolbnitz station under construction.

The Provincial Companies (Landesgesellschaften) operate the medium- and high-tension systems and

* "Austria's Hydro-Power Resources and their Utilisation for European Power Supply." Published by the Federal Ministry of Transport and other interested organisations.

* "The Glockner-Kaprun Generators," page 430.

Map of Austrian existing and projected hydro and thermal generating stations and transmission lines

produce part of the energy consumed locally. The Newag Company of Lower Austria operates stations on the Kamp River (Dobra-Krumau, Thurnberg-Wegscheid and Ottenstein).

The development of the Austrian power industry has been greatly stimulated by the active interest shown by ECA, which arranged for the funds to be provided for the erection of power stations and transmission lines. Austria is anxious to raise her own funds for the development of her power production and happily the rate of self-financing is slowly but gradually rising. The Government intends to raise a domestic loan for this purpose, but it is realised that domestic financial possibilities will not permit the development of the Austrian power industry to cover all future demands.

Since 1945 there has been a considerable increase in the demand for power throughout Europe. The efforts of the European Economic Co-operation Organisation and the Union pour la Co-ordination de la Production et du Transport de l'Electricité (UCPTE) are directed towards solving the problems imposed by the rising demand for energy by inter-European co-operation and in overcoming all technical, financial and psychological obstacles. The coal shortage is inducing countries to develop their water-power resources and to supply other countries in need of power with their excess energy.

Austria is a country which possesses hydro-power resources in excess of its own requirements and which is thus in a position to export power.

As long-term planning is required for the development of those potentialities which have not yet been exploited, the Austrian Government has formed development companies to explore and plan future schemes. These schemes have been published by the Federal Ministry of Transport and Nationalised Enterprises Electric Power Economy Section in a memorandum entitled "Austria's Hydro-Power Resources and their Utilisation for European Power Supply." This memorandum is likely to arouse a great deal of interest in Austria's water-power resources in countries needing energy.

In the Oetz valley which leads to the Inn it is planned to provide large storage reservoirs. The total plant capacity will be about 1,040 kW and the annual output about 2,200 million kWh. Utilising the Upper Inn for power generation, a capacity of about 390,000 kW could be installed and 1,320 million kWh produced annually. In the region of the Bregenzer Ache River, which flows into Lake Constance near Bregenz, large storage areas could be utilised. In the projected generating stations it is estimated that 580,000 kW could be installed and 1,270 million kWh produced in a normal year. The plans for the Eastern Tyrol group show that 400,000 kW could be installed and 1,207 million kWh produced. An important feature of these plants is that they will be capable of producing an especially large percentage of winter power.

The existing plants of the Vorarlberger Illwerke Company do not utilise all the water-power resources of the catchment area of the Ill River, although the direct catchment area has been enlarged by diversions from adjacent areas. Their production could be increased to 1,863 million kWh per annum and their capacity to 635,000 kW.

The border between Austria and Bavaria is partly formed by the Inn and Salzach Rivers. These two rivers represent valuable run-of-river energy resources. As yet only Ering and Obernberg have been completed and put into operation, while the Braunau Station is being constructed at present.

The Jochenstein station downstream of Passau on the Danube border section between Upper Austria and Bavaria has been authorised.

Along the Austrian section of the Danube eleven run-of-river stages are capable of economic development, with a total plant capacity of 1,520,000 kW yielding annually about 10,400 million kWh. An important feature of the plants on the Danube is that 44 per cent. of the power production will be generated in winter.

This survey suggests that the development of Austrian water-power resources opens up great possibilities in the way of increasing the production of electrical energy in Europe and the central position of Austria favours transmission to power-needy neighbours.

English Electric Hydro-Electric Plant During 1952

The English Electric Co. Ltd. informs us that during 1952 a further nine water-turbine generating sets and one water turbine went into commission or were completed ready for service.

The third 22 MW set at Fasnakyle was commissioned, and the North of Scotland Hydro-Electric Board scheme, of which Fasnakyle power station is the climax, was opened officially by the Duke of Edinburgh on October 13. Two 1,000 kW sets at Lussa were also put into commission for the Board.

In Spain, the third 40 MW unit at Cofrentes was completed, and in Portugal the joint contracts placed with The English Electric Export and Trading Company and the Metropolitan Vickers Electrical Export Company were brought near to completion by the commissioning of the third units in each of the two power stations, Castelo do Bode (45 MW set) and Vila Nova (39,000 b.h.p. turbine).

In January 1952, the Kolhapur station in India went into operation with two 1,500 kW units embodying Kaplan-type turbines, and the other two units are ready for service when load is available.

In 1951, too late for inclusion in last year's review of activities, a large contract was negotiated with the Tasmanian Hydro-Electric Commission for equipment for two new power stations, the details of which were worked out early in 1952. Wayatinah power station will have three 56,000 h.p. turbines driving 46,000 kVA alternators, and Lake Echo power station one 42,000 h.p. turbine coupled to a 35,000 kVA alternator. The contract includes switchgear and transformers for both stations, and part of the pipelines required.

An order has been received for the Ghost River extensions in Alberta (see page 52 of this issue) covering a 30,000 h.p. turbine, which will be manufactured by the John Inglis Co. Ltd., Canadian Associates of "English Electric."

Bituminous Paints. A descriptive pamphlet issued by George Lillington & Co. Ltd. refers to the variety of bituminous paints which they manufacture for preservative and waterproofing purposes.

Book Reviews

The Failure of Concrete Through Chemical Action (National Building Studies Research Paper No. 14, "Reactions between Aggregates and Cement. Part 1. Alkali-Aggregate Interaction: General." Department of Scientific and Industrial Research, 5-11 Regent Street, London, S.W.1.).

Attention was first drawn to the possibility of concrete seriously deteriorating through chemical action between cement and aggregates when a paper given to the American Society of Chemical Engineers in 1940 suggested that several failures of concrete structures were due to this cause. Although no large-scale failures have taken place in this country there have been many failures elsewhere and much work has been done on the problems of the causes and effects of reactions between aggregates and cements.

The present publication is the first of a series of papers which will deal with alkali-aggregate problems. It describes the early investigations in the United States and the theories on the subject. There are various chemical reactions which can be the cause of breakdown in concrete structures, one of the most important being that of siliceous aggregates with the sodium and potassium hydroxides released during the hydration of cement. The alkali silicate gel formed in this way can swell sufficient to crack the concrete. The mechanism of expansive pressure is not yet fully understood; current theories on the subject are briefly described.

The paper deals with observations made on concrete dams, bridges and buildings in U.S.A. and with tests on the types of reactive aggregates used in their construction. Test methods are described and recommendations for the prevention of expansion due to chemical reactions are given.

"Dictionnaire Technique des Barrages" (Technical Dictionary of Dams). Published by the International Commission on Large Dams of the World Power Conference, 3 rue de Messine, Paris VIII, 9·3 in. by 6 in., 169 pp., 70 ff. On sale in the United Kingdom at Lund Humphries & Co. Ltd., 12, Bedford Square, London, W.C.2. Price 25s.

This dictionary follows the generally adopted pattern of polylingual dictionaries, that is to say each term has its serial number, and both number and term appear again in the index provided at the end of the volume for each language separately. The first edition is limited to French, English (British and American version), and German. The original frame work, in the French language, and the illustrations were established by the French Committee on Large Dams under the direction of M. Mary, Chief Engineer of the Ponts et Chaussées, Paris.

The terms are divided into four main parts: I. General; II. Dams proper; III. Appurtenant Works; and IV. Construction Works. Part I covers fundamentals such as meteorology, hydrology, constitution of water reserves, geology, and petrography. Part II deals with the various types of dams, their calculation, behaviour in practice, materials used in their construction, etc. In Part III flood discharge, impounding and emptying are condensed in one chapter; further chapters are devoted to protection against scouring, syphons, various types of gates and valves, and intake works. In part IV we find the organisation and layout of construction plants, the preparation of aggregates and concrete, conveying installations, shuttering and miscellaneous equipment.

The expediency of giving the English terms in a British and an American version in separate columns may be seriously questioned; to say nothing of the fact that, to the extent of 95 per cent., both versions are similar, a single column would prove perfectly adequate if specified American terms were marked (A) or (Am) as in other polylingual dictionaries, and space would be available for a fourth language.

With regard to German terms, it may be safely assumed that the next edition of the Dictionary of Dams will be compiled with the co-operation of the German Committee on Large Dams. This is in no way whatsoever meant as a criticism of the excellent version given by two distinguished Swiss engineers, but the purge of terms of foreign origin in Germany had set in long before World War II; it is still going on, and an up-to-date revision of this column would be welcome to users who are not quite familiar with the latest additions to technical German.

In spite of its small type, printing is very clear; the diagrams are excellent, and the paper and binding are very good.

The publication of a really serviceable technical dictionary of dams was long overdue, and every credit must be given to the International Commission on Large Dams for this work, as well as to Unesco for their financial assistance.

Estatistica das Instalaçoes Eléctricas em Portugal (Statistics of Electric Installations in Portugal). Published by the Portuguese Ministry of Economy, Directorate of Electric Services, Lisbon 1950, 10 in. by 7 in., Vol. I, 40 pp., 17 graphs; Vol. II, 438 pp.

In section A to F, Vol. I gives for 1950 the general and district statistics of installed capacity, production, consumption, distribution, traction, and mode of operation referring to all power generating plants in the country. Among the operative data, the number of fatal accidents caused by electric installations is given as 42 out of a total of 65, a rather high figure. The yearly statistics from 1927 to 1950 appear in Section G, p. 29 to 36; to mention installed capacity only, there is an increase of 33,000 to 152,853 kW in hydraulic plants as against an increase of 101,156 to 192,395 kW in thermal installations. Section H, following p. 36, completes the volume with a series of excellent graphs in colours.

Vol. II gives, as usual, the complete list of hydraulic and thermal power plants, substations, transmission systems, etc., as well as exhaustive data on consumption for each district.

Statistical Yearbook of the World Power Conference—No. 6. The World Power Conference, 201-2, Grand Buildings, Trafalgar Square, London, W.C.2. Price 35s. net.

In spite of its title, this yearbook has become of necessity a biennial publication, and the present issue contains annual statistics for 1948-1950, with additional and revised statistics for earlier years and available statistics for 1951. Data on resources are also included, but only to the extent that important

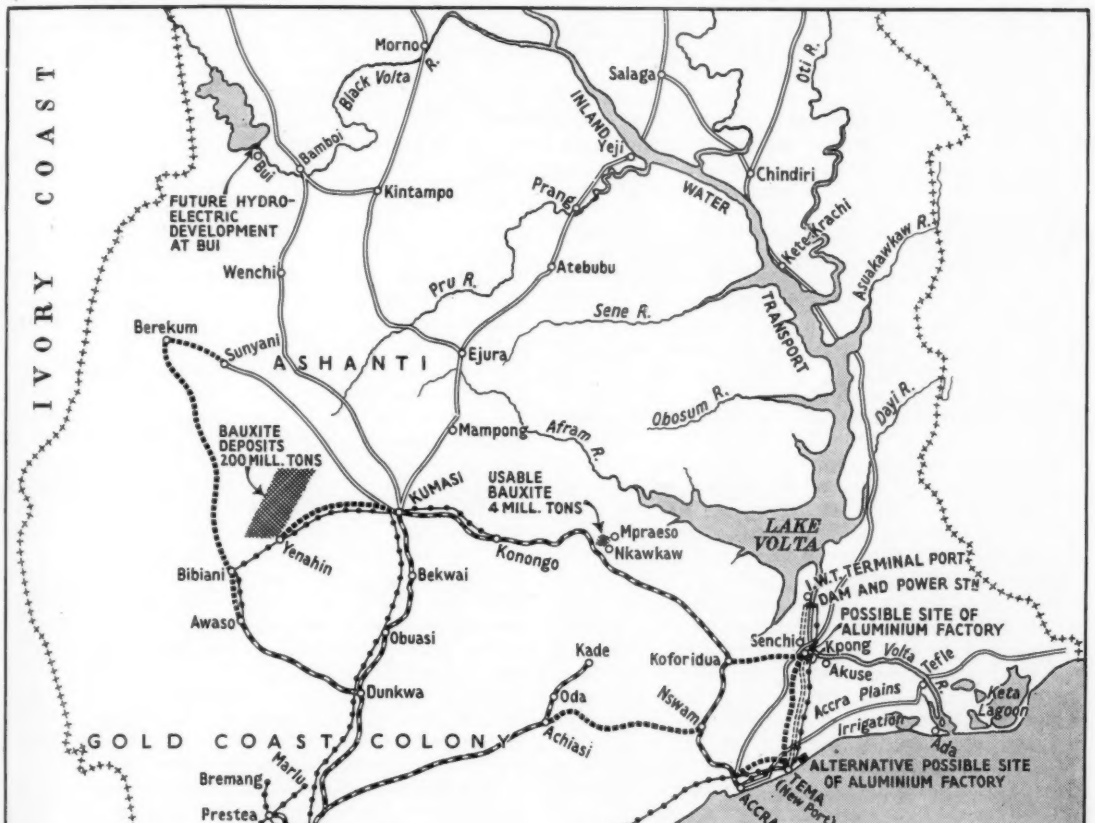
additional or revised data have become available, and reference to previous issues is needed for a complete survey. The International Executive Council of the World Power Conference has decided that complete tables on resources shall be published every six years, normally in the issue of the Statistical Yearbook published at the time of a Plenary World Power Conference.

The brief table of water-power resources is thus obviously intended as an addendum to information in previous issues. Annual statistics of developed water power are given in a succeeding table, and comprehensive statistics are given of world electricity production from all sources and of electricity consumption.

Other power sources similarly analysed are coal, brown coal and lignite, peat, coke, manufactured fuel, wood and gas.

The Volta River Scheme

WITH reference to our article on the Volta River scheme which appeared on page 26 of our January issue, by the kindness of Sir William Halcrow & Partners we are now able to publish the accompanying map which gives the most up-to-date conspectus of the scheme that is available. The map published in our January issue represented the latest information we had at the time, but is superseded by the one published herewith. It will be seen that as compared with the scheme as outlined in the previous map important additions have been made to the railway system it is proposed to build. The present map also shows proposed roadways and the projected electrical grid, as well as the position of the Volta River dam and power plant, the site of the future hydro-electric site at Bui, and the possible site of the aluminium factory. The position and extent of the bauxite deposits are also noted.



Map of part of the Gold Coast to illustrate the Volta River aluminium scheme

The Moriston Project

A summary is given of a Scottish scheme in which some unusual methods are to be employed in the construction of the dams.

WORK on the upper part of the Moriston project for the North of Scotland Hydro-Electric Board is now in hand and contracts have been placed with the Mitchell Construction Company for the construction of the Loyne dam and tunnel, the Cluanie dam and the Ceannacroc tunnel and generating station. A catchment area of 74·5 sq. miles will be developed with a total plant installation of 20,840 kW to give an estimated annual output of 66·0 million kWh.

Interesting features of the work are the use of precast concrete blocks to form both the temporary shuttering and permanent facing to the Loyne and Cluanie dams, the use of wet-ground blast-furnace slag to replace part of the cement used in the dams, and the construction of the Ceannacroc generating station underground near the foot of a high-pressure shaft.

The Loyne dam, of mass-concrete gravity design, will raise the water level of Loch Loyne 40 ft. and will have a maximum height from the bottom of the cut-off trench to the crest of the spillweir of 70 ft. About 66,000 cu. yards of concrete will be placed in the dam, the overall length of which will be 1,745 ft. Two 5 ft. diameter culverts will be formed in the dam to draw down the reservoir if required, but floods will be passed over a 225 ft. long spillweir.

Water from the Loyne reservoir will be passed to the Cluanie reservoir through a tunnel 7,600 ft. in length and of 12 ft. equivalent diameter. To take advantage of the difference in head between the two reservoirs a generating station with an installed capacity of 600 kW will be built underground at the upstream end of the tunnel. Upstream of the station the tunnel will be lined and screens and gates will be provided at the intake. Downstream of the station only the invert of the tunnel will be lined with concrete and a bulkhead gate will be provided near the outfall so that the tunnel may be dewatered without drawing down the water level in Loch Cluanie. The tunnel may be drained through an 18 in. diameter concrete pipeline running from the gateshaft to the Cluanie dam.

This dam, again of mass-concrete gravity design, will raise the water level of Loch Cluanie by 96 ft. and have a total height, from the bottom of the cut-off trench to the crest of the spillweir, of 125 ft. A bridge will be built over the 450 ft. long spillweir to provide access to the outfall gate house of the Loyne tunnel. Two 5 ft. diameter culverts will be formed in the dam both to drawn down the water level in the reservoir and to provide spates in the River Cluanie as required under the scheme. A 240 kW turbo-alternator will be provided to make use of the compensation water which has to be released at the foot of the dam. The volume of concrete to be placed in the dam will be about 232,000 cu. yards and the substitution of wet-ground blast-furnace slag for about 70 per cent. of the cement to be used in both the Loyne and Cluanie dams will release a considerable amount of cement for use elsewhere.

Just upstream of the dam will be the intake of the Ceannacroc tunnel, to be seen in our titleblock, of 12 ft. equivalent diameter, between the intake and the surge shaft, a distance of 13,500 ft. Gates and screens will be provided in shafts just downstream of the intake. A 5 ft. 11 in. equivalent-diameter tunnel will divert the flow of a burn under which the tunnel passes and a 6,000 ft. long 9 ft. 6 in. equivalent-diameter tunnel will divert the River Doe. Weirs will be built to form intakes in both cases. The main and diversion tunnels will be concrete lined throughout.

At the bottom of the 165 ft. deep, 45 ft. diameter

surge shaft a 175 ft. deep, 12 ft. 6 in. diameter shaft will be sunk, and from the bottom of this shaft two steel-lined tunnels of 5 ft. and 10 ft. diameter about 100 ft. long will run to the Ceannacroc generating station.

The machine hall of the station, built underground, will be 92 ft. long, 45 ft. wide and 48 ft. high above the station floor, and will house one 16 MW and one 4 MW turbo-alternator. A mass-concrete arch will form the roof, and the walls will probably be unlined with brick panels between the crane columns. Access to the station will be through a 900 ft. long access tunnel with a carriageway width of 12 ft. and a gradient of 1 in 9. At the entrance to the access tunnel will be the control room, transformer and switchyard. The tailrace tunnel from the station will be 1,700 ft. long and of such shape that it will not be under pressure at any time. Before re-entering the River Moriston the water will pass through a short open channel in which provision will be made for stoplogs to be inserted so that the tailrace may be dewatered.

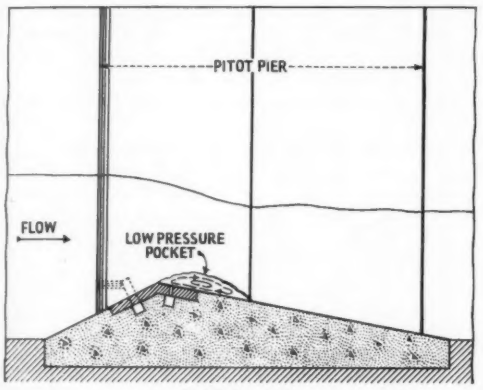
The construction of the generating station at the foot of the high-pressure shaft will save many tons of steel and at the same time simplify the design of the turbo-alternators.

By the end of November, 1952, a start had been made on the construction of camps and workshops, excavation had started at the Cluanie dam and a start had been made driving the Loyne and Ceannacroc tunnels.

The consulting engineers for the civil-enginering works are Sir William Halcrow and Partners, MM.I.C.E., for the electrical and mechanical work Messrs. Kennedy and Donkin, and the architects are Neil and Hurd.

New Stream Flow Meter

A new type of stream flow meter has been devised by the staff of the Hydraulics Research Board, Department of Scientific and Industrial Research, and is described in the recently published Report for the years 1947-1951.* The device has been designed to meet the need for a cheap flow meter which will cause little afflux and yet be suitable for the continuous measurement of discharge over a whole range of river flow. It consists essentially of a submerged weir of triangular section, as shown in Fig. 1, carrying a pier fitted with pitot tubes. The discharge Q is obtained by multiplying the free-flow discharge $Qm = 3{\cdot}58\ B.T.^{\cdot}$ by a reduction factor f, which is read off a chart relating it to P/T (Fig. 2) where B is the width of the river and P is the pressure head measured by a manometer in the low-pressure pocket in the downstream crest, T being the total energy of upstream flow measured either by a pitot tube in the nose of the pier facing upstream or by adding $V^2/50$ to the upstream reading to allow for velocity of approach. The device has been named the Crump weir and patent rights have been applied for.



SECTION A.A.

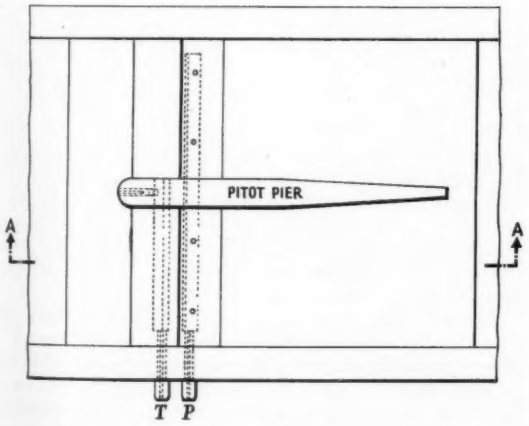


Fig. 1. Arrangement of the Crump weir

* Hydraulics Research—1947-1951. Published by H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 3s. net.

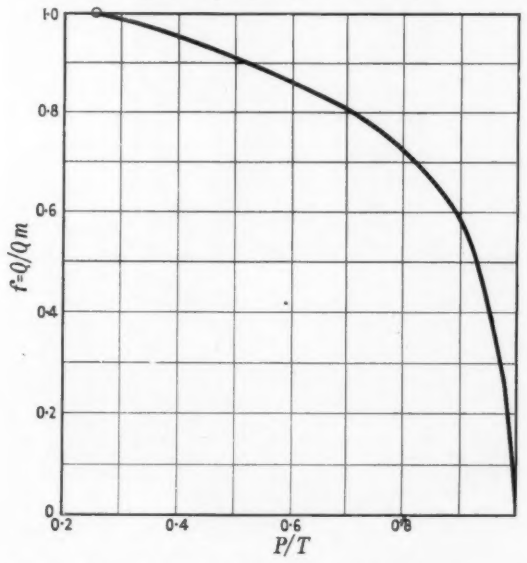


Fig. 2. Chart for ascertaining reduction factor

New Cable Control Unit

Blaw Knox Limited are now marketing a new Model "K" Cable Control Unit which has been designed for use with Class II, Group 2 (76-100 drawbar h.p.), Class II, Group 3 (101-125 drawbar h.p.) and Class III (126-175 drawbar h.p.) tractors. This new equipment is claimed to be particularly fast, positive and smooth in action. It is light in weight, simple and easy to operate and fits snugly up to the back of the tractor, reducing overhang to a minimum. Clutches give immediate and continuous response without overheating, and efficient band brakes ensure smooth and positive braking with absence of slip and shock. Access to brakes and clutches for maintenance purposes is easy. Various new features in design have been incorporated into the new unit as a result of prolonged field tests:—

(a) The top deck standard embodies full swivelling sheaves which ensure continuous and accurate winding of ropes on to the drums, thereby prolonging the life of the ropes.
(b) The diameter and width of clutches have been increased to transmit the high line pulls required for the operation of some of the newer large-capacity scrapers.
(c) Increased brake sizes have been adopted to control the high line pulls and so ensure safety in operation.
(d) Improved cam operating mechanism gives extremely light and sensitive control.

Fig. 1. Blaw Knox cable control unit

The new unit, illustrated herewith, has a line speed ranging from 287 to 503 ft. per min. and accommodates 175 ft. of $\frac{1}{2}$ in. cable; it weighs 1,910 lb. (866 kg.) net with the adaptor and 2,140 lb. (970 kg.) gross and can be shipped in a case measuring 5 ft. 10 in. × 3 ft. 6 in. × 3 ft. 3 in. Without the adaptor the net weight is 1,768 lb. (802 kg.) and the gross weight 2,094 lb. (950 kg.).

Power Unit for Large Crane

A special-purpose self-contained diesel electric generating unit made by A.C. Morrison (Engineers) Ltd., of Loughborough, is at present being employed to supply current to the 105 ft. Liebherr Tower Crane, a German product, owned by Thomas C. Wild (Machinery) Ltd., of Sheffield. This crane is now at work on an important contract at Southall, Middlesex, where the Morrison plant is not only driving the crane but is also supplying power for the concrete mixer, mortar mill, and lighting. The plant is of 25 kVA capacity and is powered by a Petter four cylinder B4 diesel, with Bryce fuel injection, direct coupled to a generator and exciter with one point automatic voltage regulator. The assembly is mounted on a base plate and enclosed in a neat box.

The crane itself has four motors to move it backwards and forwards along its rails and to raise and lower its loads. The height from the ground to the end of the traverse arm is 105 ft. The crane can handle weights of up to two tons, according to position, at 16 ft. from its centre of gravity. It is provided with an automatic cut-out to prevent the possibility of overloading.

Without the power unit the crane weighs 16 tons. It can be assembled by four or five men in a day and dismantled in about four hours. It can receive its current from the mains supply where available.

Messrs. Thomas C. Wild (Machinery) Ltd. recently invited a party of municipal and public works representatives to see the crane in operation at Lancaster, where it was used to help dismantle the cupola of the old town hall which had been declared unsafe.

From page 68

To achieve the high performance and stability of modern governors, friction must be reduced to a minimum; connecting linkages must be adequately rigid; and backlash at joints must be avoided by ensuring unidirectional force across the joint at all times. Neglect of these requirements will cause insensitivity and hunting.

A governor actuator having great rapidity of action is desirable for a hydro plant so that it can follow load changes quickly and thus provide good frequency and load control on the electrical power network. However, the action of the governor may not be more rapid than is permitted by stability considerations, as in other closed-sequence control systems where amplification is restricted by stability.

ACKNOWLEDGMENT. Figs. 1, 2 and 4 are reproduced from the author's paper "Water Turbine Governors" presented to the Institution of Mechanical Engineers on November 7, 1952. Much of the information contained in this series of articles is also repeated from that paper.

(To be continued)

Abstracts from the World Technical Press

Protection of Alternators

Under fault conditions an alternator, of approved design and construction for normal service, may be subjected to stresses which could only be catered for by uneconomic design. A two-stage protection system is advocated: a first stage to prevent or at least restrict these abnormal stresses, and a second to reduce the extent of damage resulting from breakdowns that may occur in spite of the first-stage protection.

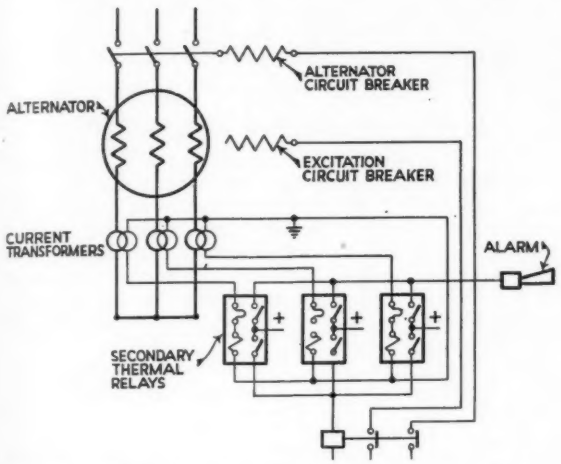


Fig. 1. Combined protection for alternator for short circuit and overload

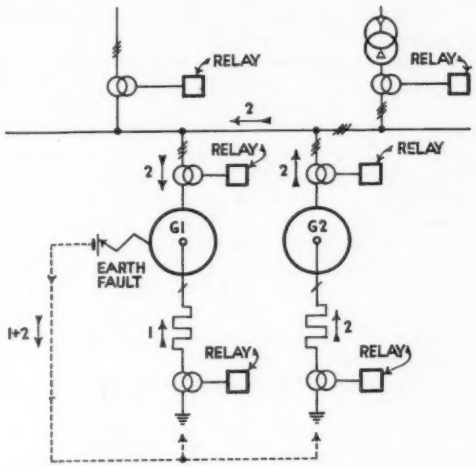


Fig. 2. Earth protection for alternators with direct connection to overhead lines

The stresses to be checked by first-stage protection are mechanical, thermal or electric; they are due to external causes and result in overspeed, short-circuits and overloads, and over-voltage respectively. Overspeed occurs here only as a reminder, since its initial cause lies in the turbine to which the alternator is coupled.

After first-stage protection has been dealt with, the possibility of restricting damage to insulating material is examined, and the conclusion drawn that such damages can efficiently be restricted by instantaneous protection against earth faults; according to the size of the alternator protection against faults between phases and eventually protection against faults between turns of one and the same phase may be added. A short paragraph on the protection of large units against fire concludes this study. (H. de Marsac, *Electricité*, Vol. 36, No. 187, October 1952, p. 205, 4 pp., 3 ff., and No. 188, November 1952, p. 229, 6 pp., 13 ff.)

Conemaugh Dam

This Army Engineer structure, scheduled to be ready for operation last November, constitutes a further link in the chain of flood-control dams in the upper Allegheny region, and forms, at the same time, a part of the flood-protection plan for Pittsburgh and the Upper Ohio Valley. It will impound flood waters arising from a 1,351-mi drainage area, and gradually release them as the downriver channels are able to accommodate them. The six dams previously completed are expected to cut about 5·5 ft. from the crest of future floods, while the new Conemaugh Dam is counted on to cut off another 4·6 ft.

Completion of the structure is expected to have an important secondary effect for Pittsburgh and neighbouring communities through enabling flood plains to be converted to industrial sites.

The principal characteristics of Conemaugh dam are: maximum height, 170 ft.; total length, 1,290 ft.; spillway length, 420 ft.; fourteen 30 × 30 ft. crest gates; thirteen 5·67 × 10 ft. sluices; volume of concrete placed, 333,600 cu. yards; rock excavated, 150,000 cu. yards; earth excavated, 130,000 cu. yards. (*Engineering News-Record*, October 30, 1952, p. 28.)

High Lines in Rough Terrain

The delivery of a large block of electric power over a considerable distance presents problems which touch upon many interesting aspects of electrical equipment and system design. Over-all cost must be kept as low as possible by selecting the most economical voltage, proper conductor size, and span length; climatic conditions, soil condition and general location of the line must be taken into account in the detail line design; the question of voltage regulation on the whole system and the need for a synchronous condenser must be carefully considered, keeping in mind the kVA load and power factor of the generator.

The author of this article deals with a recent instance involving the transmission of electric power for a distance of 90 miles over rough, mountainous country at an elevation of approximately 7,000 ft. The load to be delivered was 62,000 kW at a power factor of about 0·92 lagging, and the system was to be operated initially as an isolated system.

After a study of transmission costs made at different voltages from 110 to 230 kV, a voltage of 138,000

was chosen as it gave a low transmission cost and at the same time is a widely adopted standard voltage and thus ensured, when later required, easy interconnection with adjoining systems.

As to conductor size, 400,000 C.M. copper proved best choice but an equivalent aluminium conductor (636,000 ACSR) was substituted for cost and availability reasons.

Comparative cost studies further revealed that the most economical span length for an aluminium conductor of this voltage is about 1,000 ft.; the actual span for each structure was, however, determined after a profile of the right-of-way had been prepared, and advantage was taken of the contour of the country. The line chosen has a horizontal configuration, and the supporting structures, as shown in Fig. 1, are H-frames consisting of red cedar poles and crossarms. Higher cost and supply difficulties precluded the use of steel under present conditions. Special structures were, of course, set up for longer spans dictated by the contour of the country, as well as at any point where required, such as railway and road crossings, and at spots where the line made a sharp change in direction.

The number of breakdowns per year was kept low by careful consideration of several basic factors in the design of the line: isokeraunic level of the territory where the line is located, pertinent weather data, number of insulators in each string, spacing between conductors and supporting structure, midspan spacing from conductors to ground wires, ground wire location and design, and ground resistance.

Calculations based on Fig. 2 indicate that it would be necessary to install a 25,000 kVA condenser. A synchronous, hydrogen-cooled condenser was chosen, and installed out of doors. This condenser automatically regulates the voltage and the supply of reactive current during normal operations and during system disturbances. If this system is to be interconnected later with other systems, the condenser will aid materially in the regulation and control of the flow of reactive power between the systems.

The transient stability problem is not serious since the load is relatively steady and was very much simplified since, at the outset, this system was operating without interconnection. Circuit breakers and relays of modern normal speed were used to protect the system, while both generator and synchronous condenser were equipped with modern high-speed automatic voltage regulators. These provisions enable the system to ride through any disturbances with a good margin of safety. (F. D. Troxel, *Allis-Chalmers Electrical Review*, Vol. XVII, No. 2, 2nd Quarter 1952, p. 4, 5 pp., 9 ff.)

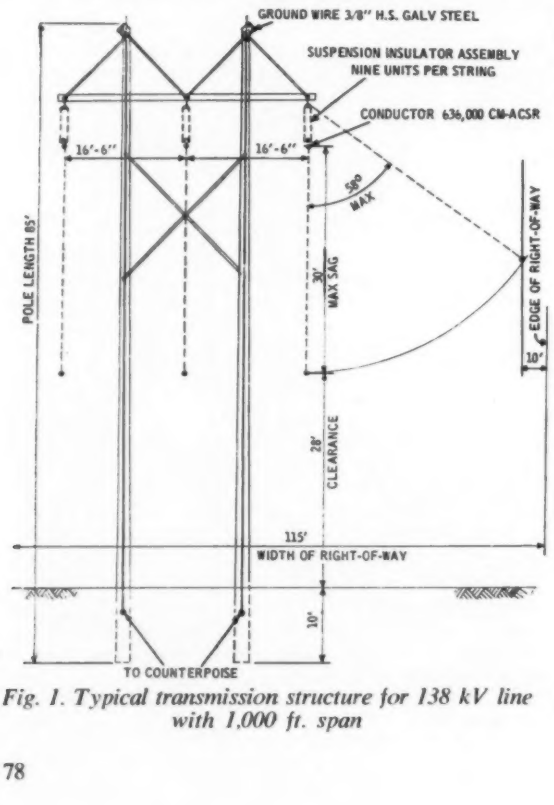


Fig. 1. Typical transmission structure for 138 kV line with 1,000 ft. span

Accident Prevention with H.V. Plant

Statistics show that accidents due to H.V. installations in Switzerland are on the increase. On the basis of the reports of the Swiss Inspectorate for H.V. plants, the causes of accidents are determined, typical cases are singled out and described, and measures to be taken to avoid and prevent accidents are suggested and discussed. (E. Sprecher, *Bulletin de l'Association Suisse des Electriciens*, Vol. 43, No. 4, 31.5.1952, p. 459, 11 pp.)

Applying the Ejection Principle to a Spillway

The spillway described in detail in this article is to be set up at the Iril Emda rock-fill dam, about 50 miles from Bougie, Algeria. It is controlled by several sluices each of which discharges into a free-flow tunnel with an outlet at about the same level as the bottom of the valley. When any single sluice is in operation, an adequate depth of water is maintained in the other tunnels, while the opening of a further sluice leads to the formation of a considerable hydraulic jump in the downstream part of the corres-

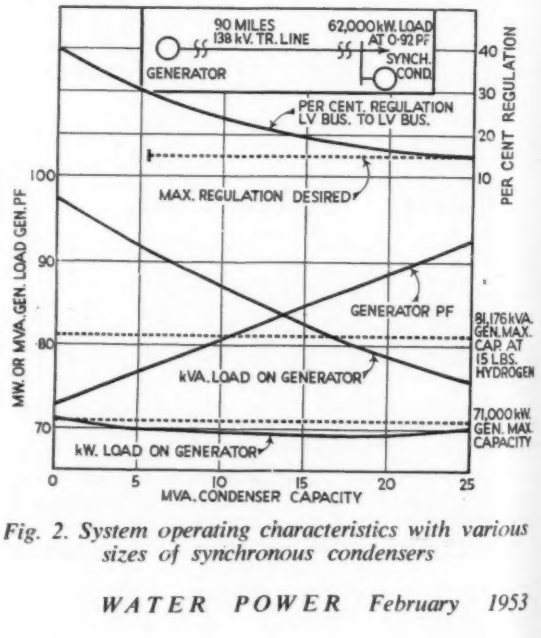

90 MILES 138 kV. TR. LINE
62,000 kW. LOAD AT 0·92 PF
GENERATOR
SYNCH. COND.
PER CENT. REGULATION LV BUS. TO LV BUS.
MAX. REGULATION DESIRED
GENERATOR PF
kVA. LOAD ON GENERATOR
kW. LOAD ON GENERATOR
81,176 kVA. GEN. MAX. CAP. AT 15 LBS. HYDROGEN
71,000 kW. GEN. MAX. CAPACITY
MW. OR MVA. GEN. LOAD GEN. PF
PER CENT REGULATION
MVA. CONDENSER CAPACITY

Fig. 2. System operating characteristics with various sizes of synchronous condensers

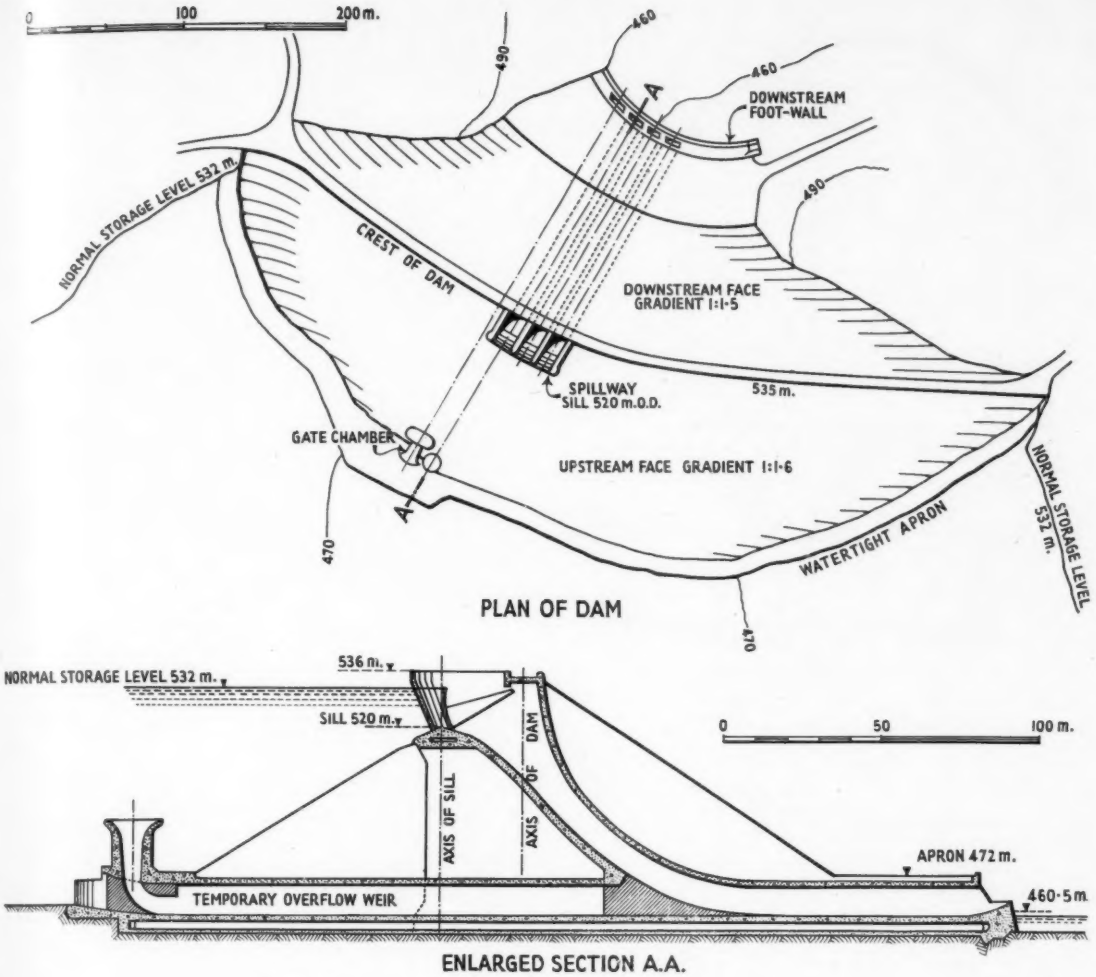


Fig. 1. Ejection-type spillway on the Iril Emda dam

ponding tunnel. This hydraulic jump may restrict the air cross-section in the tunnel to such an extent as to cause the latter to work as a pressure conduit for a short time, and scouring may result.

To avoid this risk, a dispersion system is provided, consisting of a series of appropriately shaped sills and baffles built in the downstream end of the spillway. This arrangement divides the flow discharged by each sluice into two layers, the upper layer forming a jet which scatters in the air and drops at a safe distance from the structures, while the lower division induces an ejection effect which empties the tunnels that are not in operation.

It would perhaps seem that the back flow of water over the dispersion works could only be avoided by the setting up of very large sills and baffles. The application of Tolmien's theory leads, however, to a correct ratio between the downstream level and the depth of water in the tunnels which are not in operation, and shows that this depth of water is maintained within tolerable limits, so that the height of the sills and baffles can be reduced.

The efficiency of this arrangement is proved by the fair concordance between theory and extensive model tests, and there is every reason to assume that the ejection effect will occur in actual practice in the same way as on the models, thus considerably improving the working of the spillway. (J. Chabert, *La Houille Blanche*, Vol. 7, special issue A, March 1952, p. 197, 10 pp., 24 ff.)

Rock Excavation Equipment

A comprehensive study is given of the technique of rock excavation and of the equipment used, particular attention being paid to pneumatic tools, compressors, and drilling bits. (S. C. Kale, *Indian Journal of Power and River Valley Development*, No. 9, August 1952, p. 6, 8 pp., 10 ff.)

World's Largest Underground Plant

The underground power house of the Kemano smelter projected by the Aluminium Company of Canada in British Columbia is being built in a rock cavern 82 ft. wide, 140 ft. high and 700 ft. long. The present length of the cavern provides, however, space

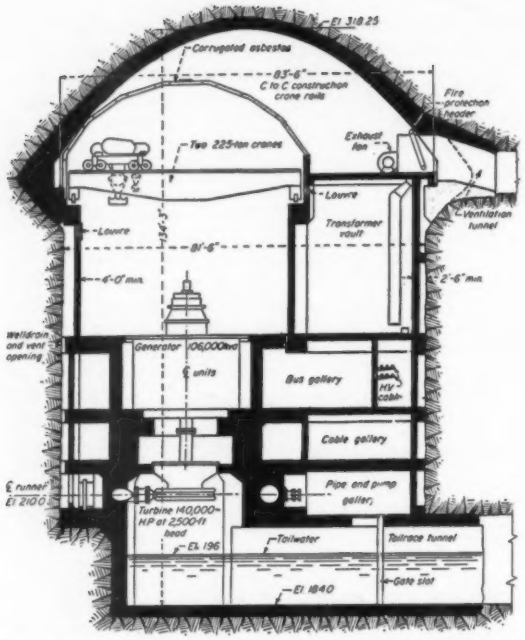


Fig. 1. Cross section through the projected power house of the Aluminium Company of Canada at Kemano in British Columbia

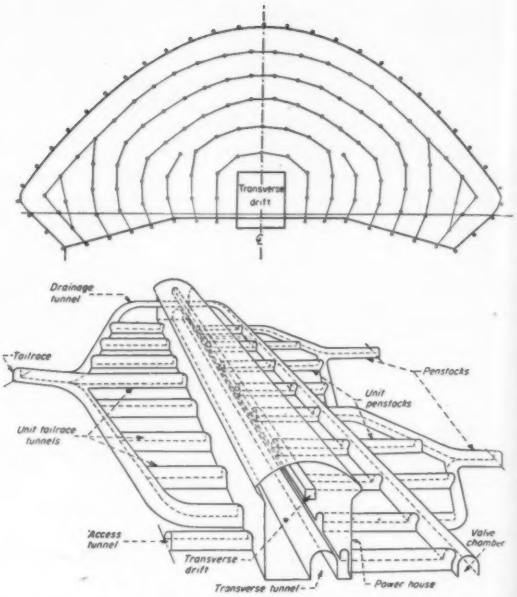


Fig. 2 (above). Drilling pattern for the power-house roof

Fig. 3 (below). Penstock, power-house and tailrace layout

for only half of the sixteen 106,000 kVA generators, and the ultimate length will reach 1,134 ft.

Invulnerability to enemy air attacks was but one of the many substantial reasons for placing the Kemano power house and penstocks underground. Other considerations were that the underground penstock is cheaper to construct, requires no external maintenance and cannot be endangered by forest fires or snow and land slides.

The excavation of 250,000 cu. yards of rock for the first increment of the power house ranks as one of the biggest single underground operations of its kind in constructional history. In addition to a cross-sectional view of the power house, we are appending a perspective drawing showing the power house, the penstock and tailrace tunnels and indicating the location of transverse drift and transverse tunnel from which the rock excavation work was started. Above the perspective drawing the drill pattern for the power-house roof is shown, from which it will be seen as many as 76 holes 110 ft. long were blasted at one time. (L. L. Wise, Associate Editor, *Engineering News-Record*, Nov. 13, 1952, p. 31, 4 pp., 7 ff.)

Determining Flood-Discharge Capacity of Spillways

In this paper, read before the Technical Committee of the "Société Hydrotechnique de France," the suggestion is made to substitute observations in space for observations in time as a basis to the assessment of the probable frequency of catastrophic floods.

If the disastrous consequences of dam bursts are to be avoided, storage dams will have to be built so as to be practically everlasting or, in other words, the structures will have to be designed to cope with the maximum discharge from the catchment area involved. But even if this maximum discharge could be determined with a fair degree of accuracy, the resulting dam would be, economically speaking, an impossible proposition.

The author ventures to assume that a major dam disaster occurs in any one country but once in an average period of fifty years; this means that in France, for instance, with about 200 dams either built, under construction or projected, provision should be made against the probability of a catastrophic flood once in $200 \times 50 = 10{,}000$ years.

However, the scarcity or deficiency of statistics resulting from the lack of hydrometric equipment in the past, and its shortage at present—especially in small catchment areas—makes it impossible to assess with a fair amount of reliability the flood discharge corresponding to such a probability.

It is therefore suggested to use as a basis of calculation, instead of a strictly limited number of observations in time, the many times greater number of observations in space, i.e. observations bearing at practically the same time on a great number of catchment areas. By providing with the necessary hydrometric equipment for 1,500 or 2,000 French catchment areas of 100 sq. km. each, it would thus be possible to collect in any of these catchment areas a mass of data equivalent to 15,000 or even 20,000 years of observation. The interpolation of these data with the known flood probabilities in large catchment areas would then enable an assessment to be made, with a fair degree of accuracy, of the flood discharge from medium-size catchment areas. (J. Duffault, *La Houille Blanche*, Vol. 7, No. B, July 1952, p. 506, 7 pp.)

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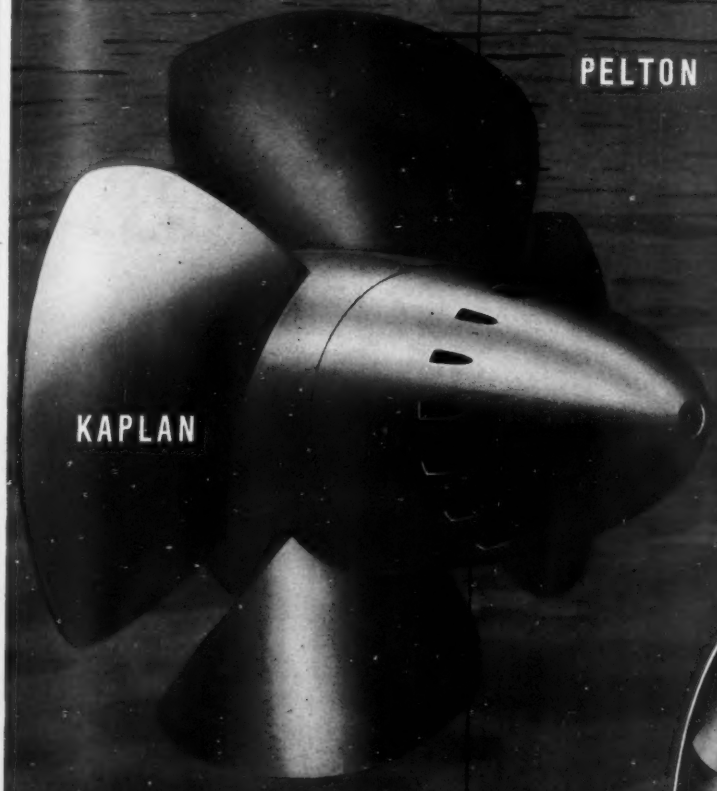

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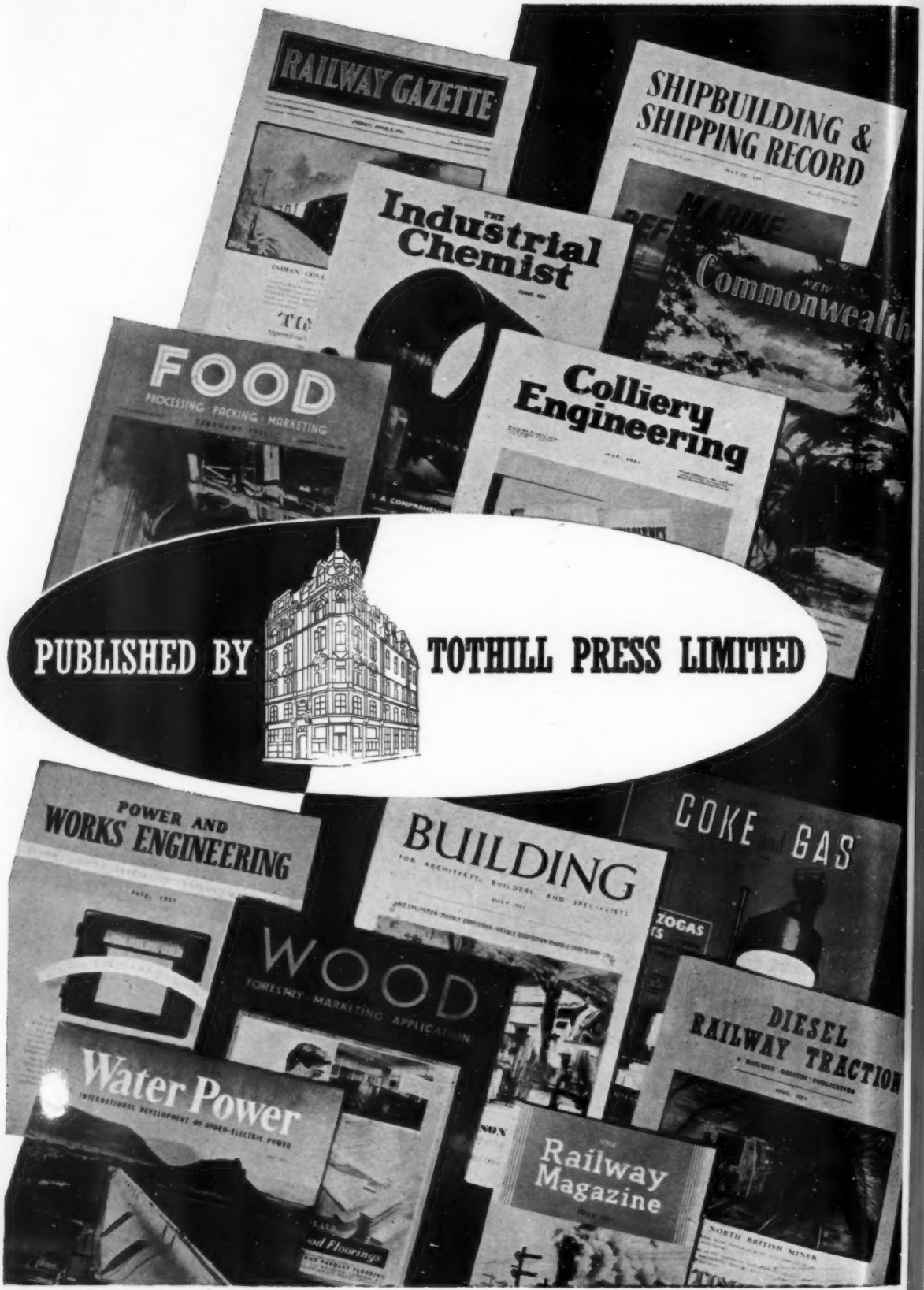

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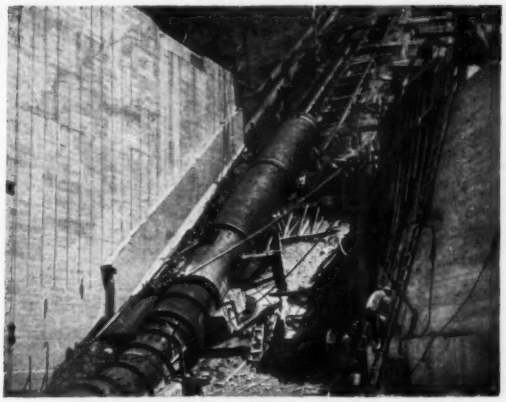
This important scheme to increase civil and industrial power resources in N.W. Portugal now approaches completion. The 300 ft. high Venda Nova dam across the River Rabagoa near its confluence with the Cavado, forms the reservoir from which water flows 1½ miles through a tunnel through intervening mountain to a valve house at the tunnel outlet. From this point a South Durham Steel pipe line carries the flow some 2,950 ft. down to the turbine house.

The South Durham steel pipe is in diameters 93″, 87″, 79″, 32″ and is electrically welded throughout with spigot and socket jointing for welding in situ. The pipe thickness is $^{13}/_{16}$″ to 2⅛″ for a working pressure at Power House of 590 lbs. per square inch. Total weight of the pipe line is 2,000 tons and all pipe and special pieces were erected, welded and tested by South Durham engineers and skilled workmen.



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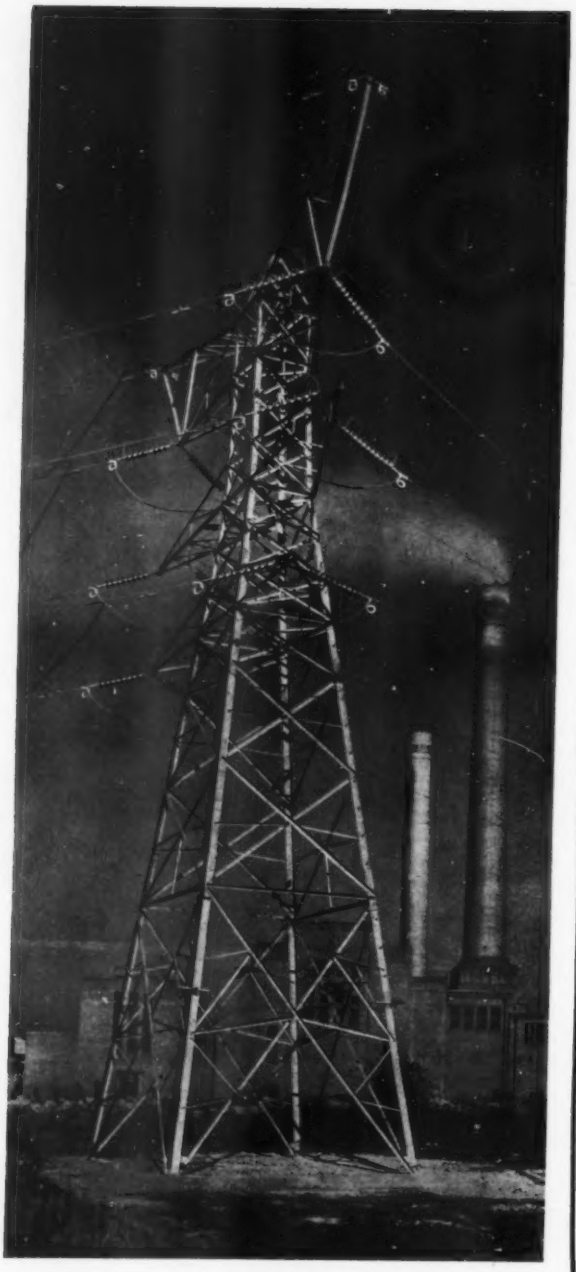

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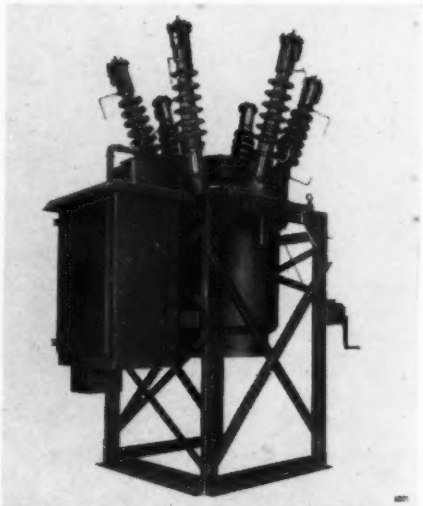

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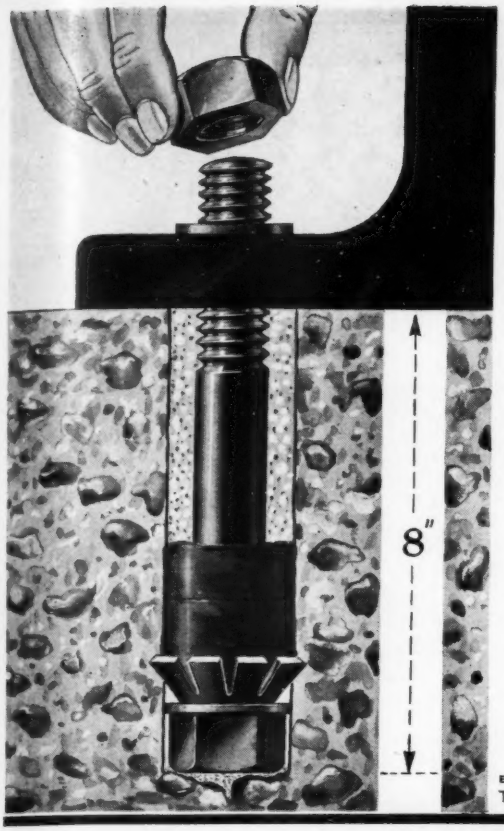

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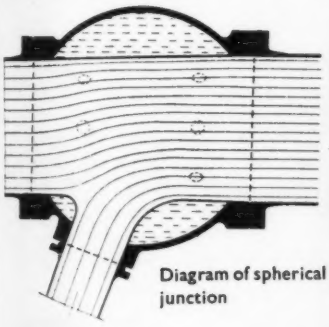
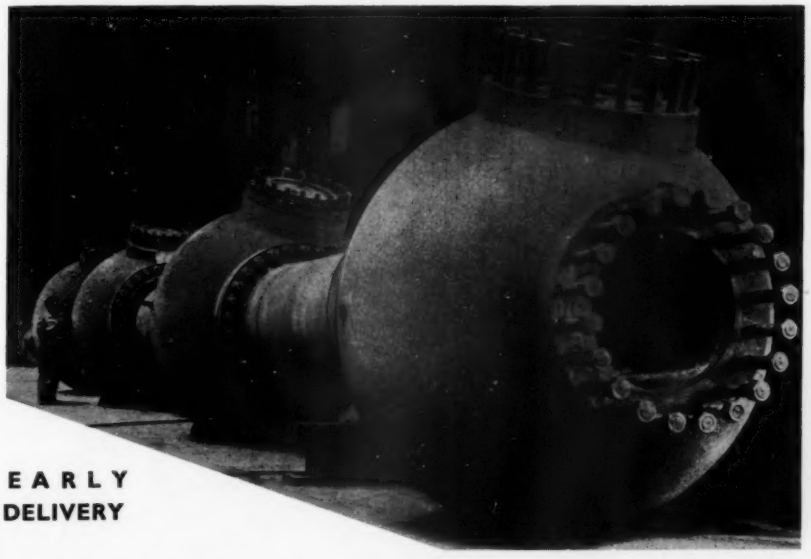


Diagram of spherical junction



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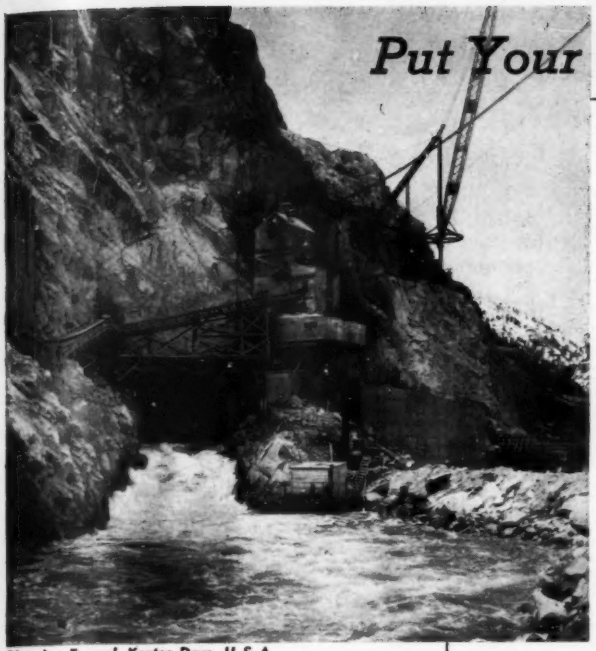

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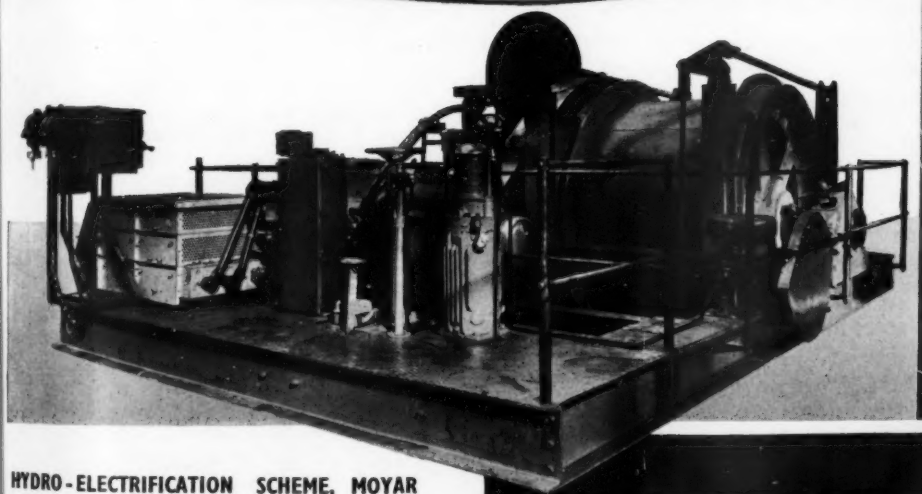

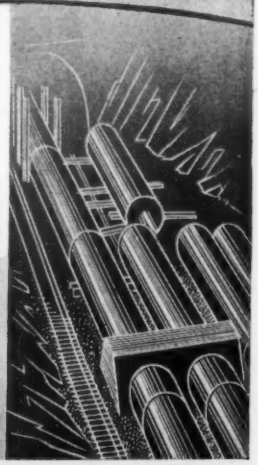

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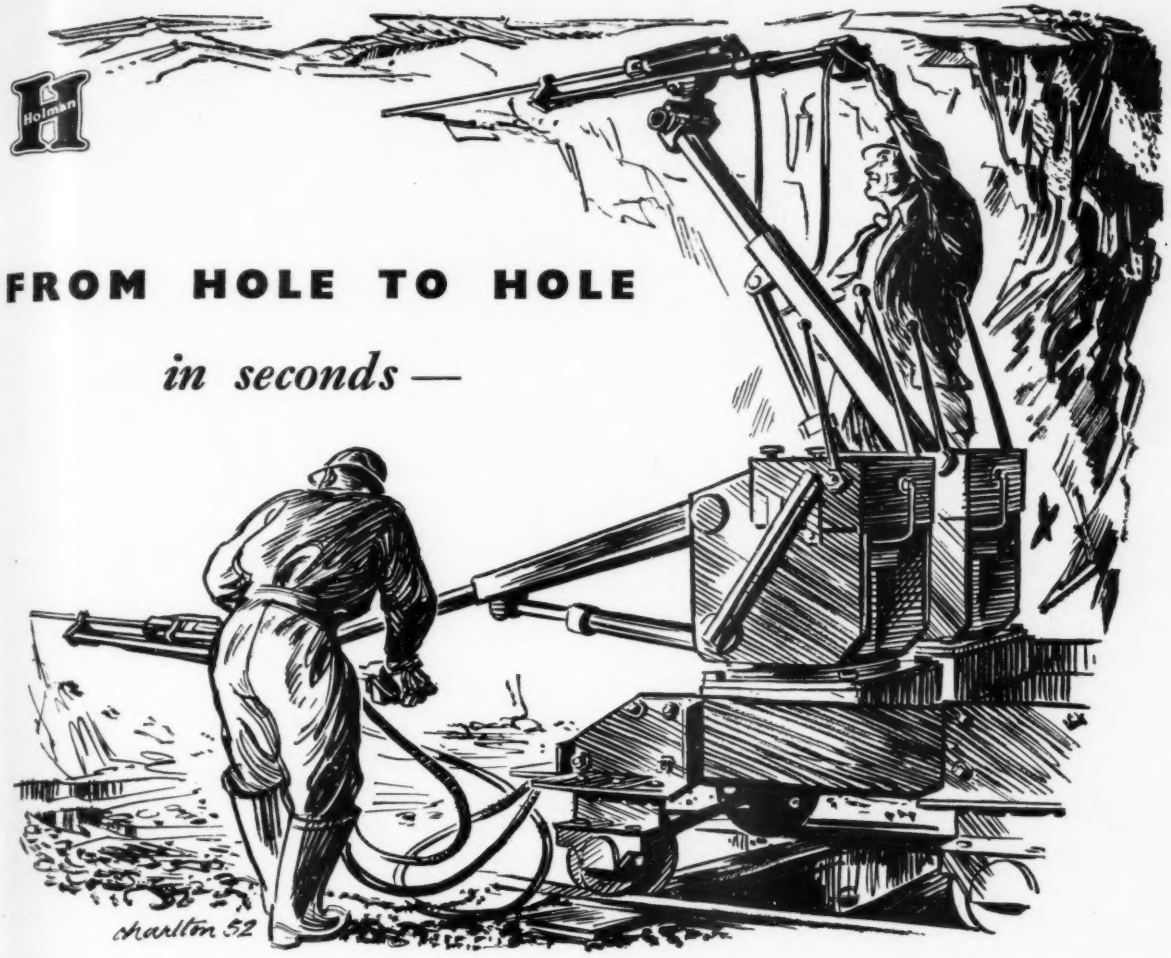

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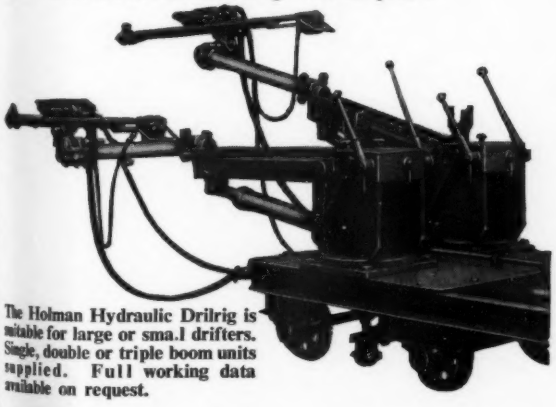

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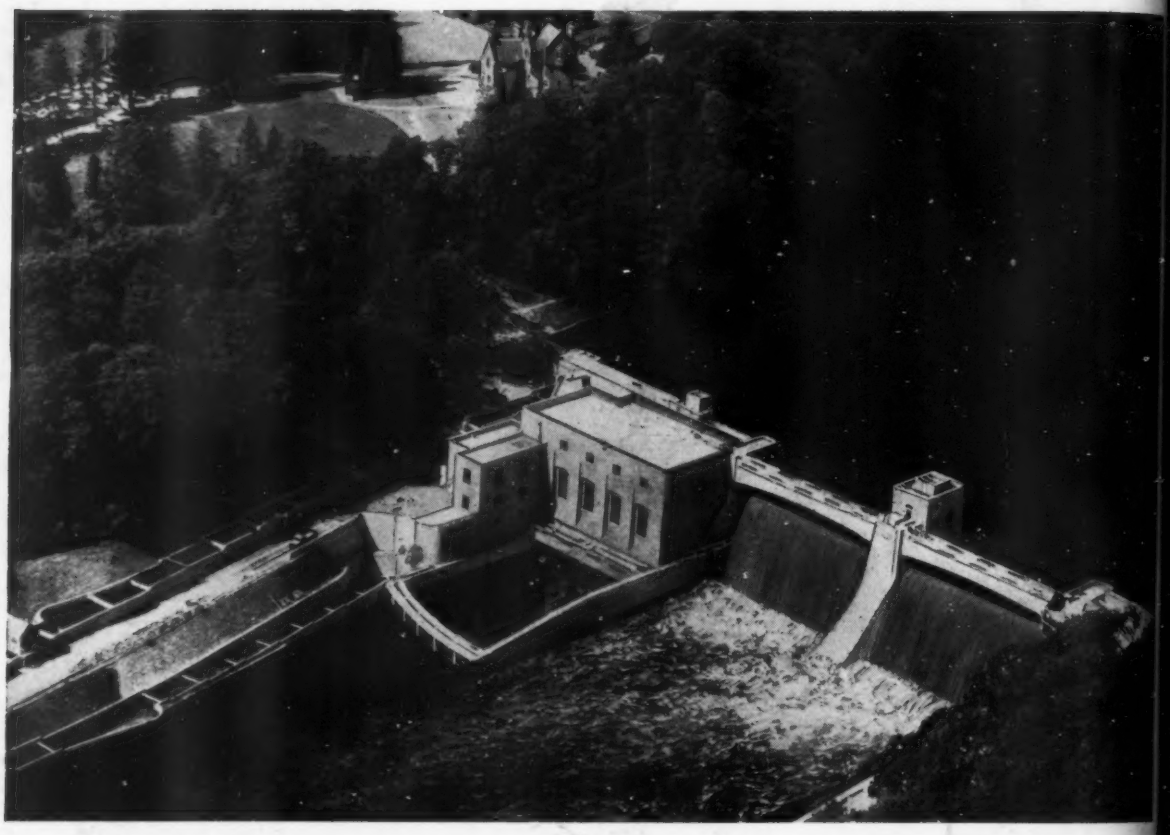

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